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University of the State of New York

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New York State Museum

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No. 44 Vol. 8

November 1901

LIME AND CEMENT INDUSTRIES OF NEW YORK

BY

HEINRICH RIES Ph.D.

CHAPTERS ON THE

CEMENT INDUSTRY IN NEW YORK

BY

EDWIN C. ECKEL C.E.

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PREFACE

The following report on the limestones of New York state deals with their uses in the various industries, but does not include the use of limestone for building or road construction.

It is hoped that it may serve two purposes:

1 To give information to quarry owners concerning the uses of limestone and the characters which the stone should possess, to make it of value for these different applications.

2 To supply limestone consumers with information regarding the extent and character of the limestone formations of New York.

Many quarries have been visited, and samples collected for analysis; and, while the chemical work has not been carried out in as much detail as might have been desired, still it is hoped that the analyses given may serve to prevent useless search in unpromising localities. In the preparation of that portion of the report relating to the testing and manufacture of cement the writer has drawn freely on many of the works referred to in the body of the report.

The writer wishes to express his thanks to the many quarry owners who have extended courtesies to him during the course of the work, and also to Dr F. J. H. Merrill, state geologist, for many valuable suggestions.

HEINRICH RIES

Ithaca N. Y. December 1900

PLATE 1

Map of New York state showing location of limestone quarries and marl deposits and manufactories of natural and Portland cement

Galena
(North Norwich P.O.)
Chenango Lake
New Berlin Center
Davis Crossing
G O
Barbers
White Store
Lathams Corners
Rockwells Mills
Mount Upton
Parker
Guilford Center
Trestle
East Guilford
New Berlin Jc.
West Bainbridge
Bennettsville
NEW YORK ONT. & W.
O. & W.
West Stephentown
Stephentown Center
Stephentown
Garfield
Central Nassau
Wyomanock
E. Nassau
W. Lebanon
Lebanon Springs
New Lebanon
Riders Mills
Bayville
New Lebanon Center
Lebanon Center P.
Old Chatham
Mount Lebanon
Canaan Four Corners
East Chatham
Canaan
Flatbrook
Canaan Center
New Concord
Chatham
State Line
Rockd
Ghatham
Redrock
Austerlitz
BIA
Greenriver
Pittsfield
B. & A.
S
A
R
K
L

North Norwich P.O.
Chenango Lake
New Berlin Center
Davis Crossing
West Stephentown
Stephentown Center
Stephentown
Garfield
Central Nassau
Nassau
Wyomanock
Lebanon Springs
New Lebanon
Lebanon
Chatham
Old Chatham
Barbers
White Store
Lathams Corners
Rockwells Mills
Mount Upton
Canaan
Flatbrook
Pittsfield
Chatham
Ghent
Redrock
State Line
East Guilford
Trestle
New Berlin Jc.
West Bainbridge
Austerlitz
Greenriver
Bennettsville
C O
B I A
S
A
L

LIME AND CEMENT INDUSTRIES OF NEW YORK

ORIGIN OF LIMESTONE

Limestones may be of either organic or chemical origin, those originating in the former manner including the more extensive known deposits, while the more local ones are confined chiefly to the second class.

Most surface waters contain carbonic acid and some organic acids in solution, and these, in percolating through rocks containing carbonate of lime, take the latter into solution in the form of an unstable bicarbonate. On coming in contact with the air, the latter is deposited either as stalactitic growths in caves, or on the surface around the spring formed by the issuing water. Such a deposit is known as travertin, tufa or calcareous sinter. In the United States extensive deposits of this type are unknown, but many local ones occur. The mammoth hot spring terraces in the Yellowstone park are examples of this, and in New York state deposits are found at many points, the best known perhaps being the so-called "petrified marl" at Mumford, and the tufa deposits near Clinton (N. Y.) In parts of Europe, specially Italy, large deposits of tufa are also known to occur. These deposits are all of fresh-water origin.

It seems probable that the deposition of the carbonate of lime may be due at times to the action of the atmosphere; still in some instances the lower forms of plant life undoubtedly play a part.

C. A. Davis has recently shown[1] that in many Michigan lakes the deposition of marl is still going on, and points out that the precipitation takes place on the surface of certain small plants belonging to the Characeae.

The precipitation may be caused in two ways. 1) If the water contains lime salts in excess, held in solution by carbon dioxid, the former will be precipitated when the latter is taken up by dioxid. It rarely occurs perfectly pure, the impurities seldom falling below 1%, while they may increase to such an extent as to prohibit calling the rock a limestone. The impurities commonly present are silica, alumina, iron, magnesia and organic matter. Traces of sulfuric acid are also met with.

---

[1] Jour. geol. 8: 485.

The silica may be present either as pure quartz; combined with alumina in the form of clay; or less frequently as an element of silicate minerals such as mica, hornblende or pyroxene. Silica may practically be looked on as an inert impurity displacing so much carbonate of lime. At high temperatures, however, when the carbonic acid has been driven off and oxid of lime left, the silica will flux the lime with great eagerness. Alumina is usually present as clay. With an increase in the percentage of the latter, limestone passes into cement rock. If present to the extent of only 4% or 5%, alumina is an inert impurity like silica, but, when present in larger amounts as a constituent of clay, it facilitates the expulsion of the carbonic acid gas. The reason for this is that clay contains chemically combined water, which passes off only at a red heat or at the same time as the carbonic acid gas. This provides an atmosphere of watery vapor into which the carbon dioxid escapes quicker than it would if passing off into gas of its own kind.

Iron and alkalis, if present in appreciable quantity, render the limestone more easily fusible, and may necessitate the handpicking of the burned rock to separate clinkers. Limestones often contain appreciable amounts of magnesia. When the amount of MgO is 5% or higher, they are called magnesian limestones, but, when it reaches 18% or 20%, the term dolomite is more frequently employed. Organic matter is rarely absent from limestones, and a very small amount may impart a gray or even black color to the rock. While a total of 4% or 5% of impurities does not mean much when only a few tons of stone a day are used, it becomes an appreciable item when the consumption at one works amounts to 200 or 350 tons of limestone a day.

Limestones may be divided into lime rock and cement rock. The former when burned slakes, or falls to pieces in water with the evolution of heat. The latter when burned does not slake but forms a hard mass on the addition of water. The two kinds grade into each other, and under each group several subdivisions can be made, as below.

- Limestones
  - Lime rocks
    - Limestone
    - Magnesian limestone
  - Cement rocks
    - Slightly argillaceous limestone
    - Argillaceous limestone
    - Argillaceous magnesian limestone

This classification is based on the composition and uses of the rock.

Whether dolomites have been derived by direct chemical precipitation or by secondary changes has been much discussed, some arguing for the former method of origin; but many for the latter, admitting the first explanation to hold good in only a few cases.[1]

It is definitely known, however, that dolomite is at times formed by the replacement of some of the lime carbonate of a pure limestone by magnesium carbonate. This process of dolomitization is accompanied by a shrinkage in the rock.[2]

---

[1] **Geikie, A. Textbook of geology.** Ed. 3. p. 321.

[2] Zirkel, F. Lehrbuch der petrographie, 3: 509. Orton, E. 8th an. rep't U. S. geol. sur. pt 2, p. 641.

Table showing variation in composition[1] of limestones

	SiO_2	Al_2O_3	FeO Fe_2O_3	CaO	MgO	CO_2	H_2O	Insol.	$CaCO_3$	$MgCO_3$
Living organisms										
1 Coral	....	....	....	54 57	....	....	2.54	....	97.46	....
2 Reef rock	....	....	....	53.82	1.01	....	....	....	96.11	2.13
3 Lagoon sediment	....	....	....	54.58	.85	....	....	....	97.47	1.79
4 Coral	....	....	....	44.96	3.87	....	....	....	80.29	8.14
5 Oyster shells	....	....	....	44.1	1.3	35.4	14.5	....	79.28	2.73
6 Calcite	....	....	....	56	....	44	....	....	100	....
7 Dolomite	....	....	....	30.43	21.72	....	....	....	54.35	45.65
Marine limestones										
8	.63	.55		55.6	.23	....	....	....	99.3	.49
9	....	1.06		53.78	.34	....	.9	1.13	96.04	.72
10	....	....	1.25	53 89	.1	....	....	....	96.24	.21
11	1.84	.64	1.52	51.4	2.23	41.19	.27	....	91.8	4.68
12	12.34	7		44 41	.44	....	....	....	79.3	.92
13	3.77	.08	6.8	33.79	15 32	42.21	....	....	60.35	32.61
14	....	.55		29.54	21.08	....	1.52	.6	52.75	44.28
Waterlime										
15	18.34	7.49		37.6	1.48	....	3.94	....	67 14	2.9
16	15.37	11.38		25.7	12.41	....	1.2	....	45.91	26.14
Silicious										
17	....	1.2		17.69	10.59	....	1.24	43.72	31.6	22.24
Fresh-water limestone										
18	....	.37		54.16	.15	43.68	....	1.49	96.71	.31
19	....	1.83	.22	34.2	.11	26.79	4 64	31.28	61.07	.23
Travertin										
20	.08	.15		53.53	.9	41.79	1.43	....	94.97	.43

---

[1] Kemp. Handbook of rocks, p. 70.

SOURCES

1 Sharples, S. P. Staghorn coral. (*see* Am. jour. sci. Mar. 1871. p. 168)
2 Hogbom, A. G. Bermuda coral reef rock. (*see* Neues jahrb. 1894. 1: 269)
3 —— Bermuda coarse lagoon sediment. "
4 —— Average of 14 analyses of the coral Lithothamnium. (*see* Neues jahrb. 1894. 1: 172)
5 Oyster shells. (*see* Geol. of New Jersey 1868. p. 405)
6 Calculated from $CaCO_3$
7 Calculated from $CaCO_3$, $MgCO_3$
8 Olcott, E. E. Crystalline Siluro-Cambrian limestone, Adams, Mass. For marble
9 Limestone, Bedford Ind. (*see* Min. ind. 3: 505)
10 Solenhofen lithographic limestone. (*see* G. P. Merrill. Stones for building and decoration, p. 415)
11 Egleston, Thomas. Limestone, Hudson N. Y.
12 Trenton limestone, Point Pleasant, O. *Vide no.* 10
13 Surface rock, Bonne Terre Mo.
14 Limestone, Chicago. (*see* Min. ind. 4: 508)
15 Hydraulic limestone, Coplay Pa.
16 Hydraulic limestone, Rosendale N. Y. (*see* Min. ind. 2: 49)
17 Silicious limestones, Chicago Ill. *Vide no.* 14
18 Woodward, R. W. Miocene limestone, Chalk Bluffs Wy. (*see* 40th par. sur. 1: 542)
19 Brewster, B. E. Eocene limestone, Henry's Forks Wy. (*see* 40th par. sur. 1: 542)
20 Whitfield, J. E. Travertin below hotel terrace Yellowstone park. (*see* 9th an. rep't director U. S. geol. sur. p. 646)

GEOLOGIC OCCURRENCE

Beds of limestone occur in deposits of almost every geologic age from Archaean to Tertiary. In New York state they are found in every formation except the Carboniferous, Triassic and Cretaceous.

Geologic age can not be looked on as an indication of purity or extent.

In New York the purest limestones come chiefly from the Trenton, though some are found in the Cambrian. Those of the Helderberg rocks seldom average over 92% lime carbonate. The

Guelph division of the Niagara, and the Cambro-Silurian (of Westchester county) yield the best dolomites.

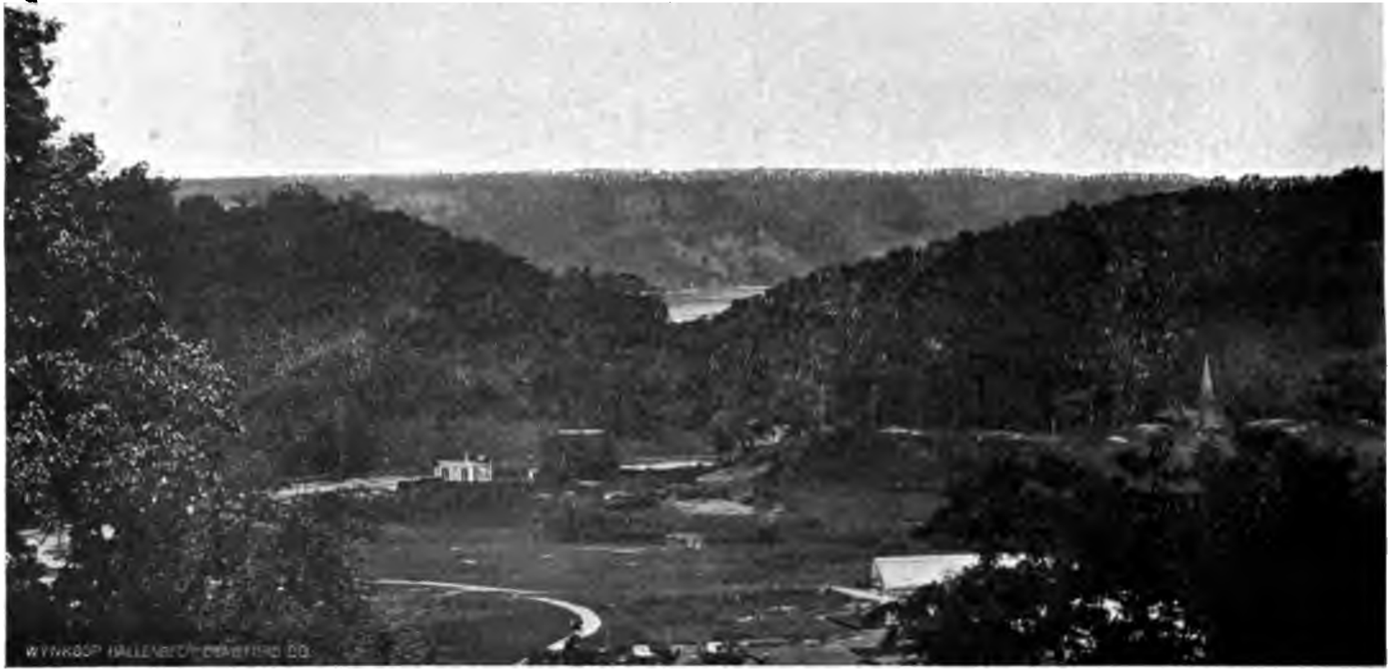
PROSPECTING

The points to be considered in prospecting are topography, vegetation and appearance of outcrops.

Limestones as a rule weather quite readily, but the presence of impurities may exert an important influence in this respect. Pure limestone is easily soluble in carbonated water, consequently, when a bed of soft, pure limestone is inclosed between two harder rocks, dipping at high angle, the limestone may be dissolved away, leaving a valley between the more resistant layers. This fact is often noticed in Westchester county, where the section involves a basal gneiss, a limestone, and an overlying mica schist; the beds have been much folded, and the dip is often steep. Most of the valleys in this county exhibit gneiss on one side and mica schist on the other, while the intermediate limestone has been cut down by weathering to form a valley. (Pl. 2)

Many limestones contain sandy layers or chert nodules, or in some cases silicified fossils. In such instances the weathering of the rock is extremely irregular, the lime carbonate being dissolved out, while the silicified portions stand out in bold relief on the weathered surface. Limestones of great purity, however, may at times weather unevenly, solution for some reason not well understood, taking place along certain lines, thus producing a series of reticulated gashes extending inward from the surface of the rock.

In magnesian limestones the carbonate of lime is dissolved out, while the carbonate of magnesia yields but slowly to solution, the result being that the rock breaks down into a series of sand-like grains. The Guelph limestone of western New York shows this. Many dolomites, however, owing to the coarsely crystalline structure and insolubility, disintegrate rather than decompose,



H. Ries, photo.

View of Inwood, Manhattan Island. Plain of Calciferous Trenton-limestone. Hills right and left of Hudson river schist. Palisades (Triassic) in the background

and in Westchester and Dutchess counties the outcrops of the crystalline dolomites are often found surrounded by an accumulation of white sand.

The position of the beds is a feature of considerable economic importance, specially when those in a quarry are of different quality. In the case of a steep dip the advantages are the possible extraction of the required layers without the necessity of disturbing the others, while the disadvantages are increased cost of hauling the rock to the surface, the deeper down we go, unless the entrance to the quarry happens to be at a lower level than that from which most of the stone is taken; with steeply dipping layers the rock may be weathered to a much greater depth than in the case of horizontal ones, because the upturned edges furnish a ready means of entrance to the weathering agents. In the extraction of individual layers the inclosing ones must be supported either by timbering or else by leaving pillars of rock; and, as quarries operated in rocks with a steep dip are often apt to go to much greater depth below the surface than other quarries, there may be an increased cost for timbering.

In the case of horizontal layers we have the advantages of having the haulage of the rock nearly all at the same level; the quarry will often drain itself; there is much greater space to work in and consequently the depth of the quarry can be much greater; the rock as quarried can often be loaded directly on the cars, the tracks being run into the quarry. The disadvantages of this method are that, if only certain layers are required or can be used, the upper ones have to be first removed in order to reach the desired beds of stone so that there is often much stripping.

This variation in dip must be carefully watched in some regions where the rocks have undergone considerable folding, as in the Hudson valley from Catskill to Kingston. Here at times the beds are nearly vertical, while again, only a few hundred feet farther, they may be nearly horizontal. Jointing has both its advantages and disadvantages. While the presence of joints facilitates the extraction of the stone, yet they also serve as a ready means of entrance for the weathering agents.

Where the topography of the country is such that outcrops are scarce, the character of the vegetation may often serve as a clue to the character of the underlying rock. In New York the surface is usually covered by glacial drift and hence the bed rock exerts no influence on the tree growth, as it does in the southern states where residual soils are common. Streams which disappear in caves, and calcareous springs may also be looked on as evidencing the presence of lime rock.

In searching for calcareous beds, if the rocks are steeply tilted, it is better to follow a line at right angles to the strike, thus passing over the edges of the different upturned beds. In regions of little or no dip this plan is valueless, and a careful inspection must be made of ravines, valleys, and railroad cuttings. If the beds dip, the apparent thickness of the rock bed at the surface, measured at right angles to the strike, will be much greater than its real thickness, the difference being greater the less the dip. A rapid means of determining the real thickness of beds whose dip is under 45° is by the following rule: multiply $\frac{1}{12}$ of the apparent thickness by $\frac{1}{5}$ of the degree of dip. Thus, if the apparent thickness were 100 feet, and the dip 15°, the actual thickness would be $100 \div 12 = 8\frac{1}{3}$. $8\frac{1}{3} \times 3 = 25$ feet.

COLOR OF LIMESTONES

An absolutely pure limestone would be white, that being the natural color of calcite, but most limestones are colored either by iron oxid or organic matter. The former gives yellow, brown, red or gray colors, depending on the form of combination and stage of oxidation; while organic matter colors the limestone gray to black. A very small percentage of organic matter may color a limestone black, the black limestone of Fairhaven containing, for instance, less than 1% of impurities.

MINERALOGIC COMPOSITION

Pure limestone contains only carbonate of lime, and dolomite, if pure, would contain only carbonate of lime and magnesia. Impure limestones may contain many different mineral species. The commonest of these is quartz, which may be present either in the form of tiny grains or else as nodular masses (chert), popularly known as flint. Clay is also a frequent impurity, and iron oxid is common in some as a cementing material.

The greatest variety of minerals is usually found in those limestones which have been subjected to contact or regional metamorphism, as this causes a segregation and rearrangement of the original impurities of the rock, yielding new mineral compounds. Among the commoner minerals thus formed are pyroxene, amphibole, garnet, vesuvianite, epidote, zircon, wernerite, wollastonite, graphite, etc.

The many crystals of white pyroxene in the Westchester county dolomites, and the bunches of dark minerals in the limestones of the Adirondack region, and in those around Mt Adam, in Orange county, are examples of this.

In weathering the more silicious layers, or spots in the limestone, stand out in relief on the weathered surface, so that this often serves as a clue to the amount of mineral impurities which the rock contains.

Texture

Limestones, unless metamorphosed, are commonly fine grained, and may vary from fine earthy rocks to granular ones. Metamorphic limestones are often coarsely crystalline.

The hardness of the rock (not of the individual grains) will depend partly on the cementing material which binds the grains together and partly on the shape of the grains themselves, whether rounded or angular. The latter will have a tendency to interlock. The relative hardness of a limestone may affect its commercial value in several ways. If too hard, the cost of quarrying it becomes great, and it will be more difficult to burn, whereas, if soft, it may tend to break up or pulverize in burning and consequently clog up the kiln. If we must use a silicious limestone, it is best to have one in which the silica is evenly distributed.

USES OF LIMESTONE

Limestone is used in the industrial arts to a large extent in either its raw or burned condition, and in the following pages an attempt has been made to describe 1) the uses of common and magnesian limestone 2) the uses of lime, and 3) argillaceous limestones or cement rock.

Paper-making

Much paper is now made from wood pulp, that known as sulfite pulp being a superior grade, in whose production considerable quantities of both dolomite and limestone are used. The following description of its use has been kindly furnished to me by T. A. Howard, of the Vermont marble co.

The broken stone is thrown into cylinders, 8 feet in diameter and 20 to 160 feet high. When the tubes are full, fumes of sulfur~~ic~~ous acid are led into the bottom, and water allowed to trickle down from the top. The stone thus becomes slowly dissolved, and the liquor is drawn off into storage tanks. This solution is used to "cook" the wood. The latter is cut into chips one or two inches long, and put in a "digester" holding seven or eight cords of wood. The liquor is also introduced, and the mixture heated by steam is under pressure for several hours. The sulfite of lime or magnesia removes all the pitch and everything except woody fibers, and at the same time removes all discoloration.

Some manufacturers say that the liquor can be made faster and stronger by the use of dolomite, in order to get which they sometimes go 10 or 12 miles from a railroad. When limestone is used, the cylinders generally seem to be made higher. In New York state dolomites are available in Westchester, Dutchess, Monroe and St Lawrence counties specially.

Glass-manufacture

The lime contained in glass is commonly added to the mixture in the form of crushed limestone, this being preferable to the burned rock, which may change in composition by the absorption of water or carbon dioxid from the air. Limestones containing iron oxid or magnesium carbonate should be avoided, since the former colors the glass and the latter makes it less fusible. Dolomitic limestones are used, however, in glass-making.

Next to silica lime is the most important of glass-making materials, as it renders the soda and potash of the glass less soluble and promotes the fusion of the materials, thus improving the quality.

Glass rich in lime requires a higher temperature to melt and, because of this, is more destructive to the pots, but, used in proper proportions, lime promotes the fusion, aids in the decomposition of the materials and improves the quality of the glass. Lime glass can not compete with lead glass in brilliancy, but it is harder, not so easily scratched, holds its polish longer, is more elastic and consequently tougher, will stand higher temperature, resists better the action of water and chemical agents, and is much more cheaply produced. On account of the slight difference in specific gravity of the two substances composing it, lime glass is also less liable to striation. In the manufacture of plate glass, which is ground and polished, it is found that glass which is rich in lime is harder to polish than that poor in lime, but holds its polish better and longer, and also increases its resistance to weathering, as well as preventing it from "sweating", which happens in glass having an excess of alkalis. It may devitrify from the presence of excess of lime, as when an excess of lead or sand is used. The lime should be as free from impurities as possible, specially oxid of iron.

Below are given two analyses, no. 1 from Blair county (Pa.) and no. 2 from Sandusky (O.) The former is used for window glass, the latter for lime flint glass.

Organic matter	.09	.05
Silica	1.01	1
Alumina	.02	.4
Ferric carbonate	.165	.....
Magnesium carbonate	1.48	41.43
Lime carbonate	97.23	55.6
Ferric oxid	.....	.12
Moisture	.....	.4

In the manufacture of tableware lime furnishes a cheap substitute for lead.

Furnace flux

This is one of the commonest uses of limestone. It is used as a flux for both lead and iron ores. In the blast furnace the action of the limestone is to reduce the iron to its metallic state and also flux the impurities, which pass off as slag. The purer the limestone the more efficient will be its action and the cheaper its use, for it will be easily seen that the greater the percentage of impurities the more limestone will be required to do the same amount of work. For reasons of economy blast furnace operators often use less pure but more easily and cheaply obtained limestones.

Some time ago a table was prepared by J. M. Hartmann,[1] giving the value of limestone containing varying amounts of silica, lime and magnesia. The basis of the calculation is magnesian limestone at 56c a ton and fuel at $3.50 a ton, both at the furnace.

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[1] Mineral resources of U. S. 1883–84, p. 670.

Values of various limestones

LIMESTONE			MAGNESIAN LIMESTONE											
Silica per cent	Lime per cent	Value cents	Silica per cent	Lime per cent	Magnesia per cent	Value cents	Silica per cent	Lime per cent	Magnesia per cent	Value cents	Silica per cent	Lime per cent	Magnesia per cent	Value cents
0	55	57	0	37	16	64	0	41	12	61	0	45	8	59
1	54	54	1	37	16	61	1	41	12	58	1	45	8	56
2	53	51	2	36	16	58	2	40	12	56	2	44	8	53
3	52	48	3	36	16	56	3	40	12	53	3	44	8	51
4	51	45	4	35	16	53	4	39	12	50	4	43	8	48
5	50	42	5	35	16	50	5	39	11	47	5	43	7	45
6	50	39	6	34	15	48	6	38	11	45	6	42	7	42
7	49	36	7	34	15	45	7	38	11	43	7	42	7	40
8	49	33	8	33	15	42	8	37	11	40	8	41	7	37
9	48	30	9	33	15	39	9	37	11	37	9	41	7	34
10	48	27	10	32	15	36	10	36	11	34	10	40	7	31
11	47	25	11	32	15	34	11	36	10	32	11	40	6	29
12	47	23	12	31	14	31	12	35	10	29	12	39	6	26
13	46	20	13	31	14	28	13	35	10	26	13	39	6	23
14	46	17	14	30	14	25	14	34	10	23	14	38	6	20
15	45	14	15	30	14	22	15	34	10	20	15	38	6	17

Limestone in excess purifies the iron from sulfur and also prevents the reduction of the silica to silicon.

Sugar manufacture

Much limestone is used in the manufacture of beet sugar, and here again the raw material must be of the proper composition. Both clay and sand are injurious impurities, as they increase the loss in lime in making the limewater, and the clay also introduces alkalis into the sugar juice. The sugar manufacturer considers that every part of insoluble matter means a loss of three to four parts of carbonate of lime. When, therefore, a limestone containing 95% carbonate of lime is paid for as if containing 100%, a stone with 85% should only be paid for as if containing 60% to 70%. If the lime is to be used for separation, the presence of much magnesia is injurious for the reason that it will not unite with the sugar as the lime does, forming a monosaccharate of lime which is essential before precipitation takes place. Consequently a large amount of magnesia hydrate in the lime necessitates the use of so much more of the latter and may also cause loss in sugar. A limestone to be used in sugar manufacture must not have more than .25% alkalis.

The following are analyses of limes used by German beet sugar manufacturers.[1]

	CaO	Al_2O_3 Fe_2O_3	MgO	K_2O Na_2O	H_2S	SO_3
Limhamn, Sweden ...	95.6	1.62	.79	.03	....	....
Plymouth, Eng.......	95.22	2.44	....	...	....	....
Gogolin, Ger. (?)	89.82	7.28	1.04	.03	....	....
Gr. Kunzendorf, Ger.	96.66	1.1	.86	.05	....	....
Ober-Kauffung, Ger...	97.72	1.2	.7	.06	....	.15
Kösen, Ger.	97	1.52	.92	.01	....	....
Osterwiek...........	93.06	5.8	....	...	....	tr
Lauffen	90.12	7.6	2.19	.03	....	....
Atzendorf	89.04	8.8	1.24	.05	much	much
Borne	78.24	13	2.24	.06	....	....
Rüdersdorf..........	94.76	2	.74	.03	....	....

It will be noticed from the above analyses that in most of the samples the percentage of lime is over 90%, though in some it is under 80%. Another noticeable feature is the low percentage of both magnesia and alkalis, specially the latter. One shows the presence of much H_2S and another of appreciable amounts of SO_3.

It is the custom for beet sugar manufacturers to burn their lime themselves, for the reason that the carbon dioxid gas is also used in the process. For the production of the best results, it is therefore important that the limestone shall be of proper quality, and the burning conducted in the right manner.

Silica is a deleterious impurity, as it not only causes the stone to fuse but also lowers the amount of lime and carbon dioxid produced to each ton of stone used. This latter point is of course true with regard to any other impurities which may be present.

Too little fuel should also be avoided, as it decreases the amount of CO_2 produced. The stone used should be compact and hard. An excess of moisture, as 5% or over, should not be present, as it reduces the temperature of the kiln when first charged. Stones containing an excess of moisture also tend to split in burning. About 1% of water is the proper amount. Magnesia is not specially objectionable except when silicates are present in the stone. It causes difficulties, however, in the purification of the sugar juice; consequently it should be at a minimum. Sulfate of lime may act the same as magnesia.

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[1] Thondindustrie zeitung. 1897. p. 1165.

If silica is present, part of it passes into the juice with the lime and retards the filtration process by coating the cloths in the filter press. Silica also forms part of the scale on the heating surface. There is less harm from this source in hard than in soft stones. Silica and alumina also tend to form an insoluble coating on the burned lumps which interferes with the slaking.

The following analyses together with most of the above information on the stones used are from a report on the beet sugar industry of the United States dep't agric., 1897, p. 205.

	1	2	3	4	5	6	7	8	9	10
Moisture..............	4.1	5.1	7.25	4.15	4.17	6 25	5.16	.52	1.21	.11
Insoluble.............	4.5	5.15	4.9	2 15	3 07	3.17	2.25	2.85	.55	.27
Organic matter	1.2	1.17	1.87	1.05	.97	1.12	.86	.3	.41	.15
Soluble silica	2.1	1.75	3.3	1.05	.98	.64	.56	.06	.2	.03
Iron and alumina oxid	.37	.41	.27	.17	.19	.15	.2	.33	.23	....
Lime carbonate .	85.86	85.12	81.67	90.18	88 65	87.98	90.03	93.8	96.58	99.1
Magnesia carbonate..	.95	.47	.59	.75	.95	.5	.45	1.81	.5	....
Alkalis	.05	.06	....	.1	.01	....	....	....	....	....
Undetermined	.87	.77	.65	.45	1	.24	.89	.84	.32	.34

Of the above nos. 1, 2, 3, and 4 are considered bad; 5, 6 and 7 are passable; 8, 9, 10 are excellent. No. 3 was used in a sugar factory and caused trouble, notably "scaffolding" or difficulty in the mechanical filters. No. 9 was substituted and these difficulties disappeared.

In looking over the analyses of limestones given in this report it will be observed that limestones of as great purity as nos. 8, 9, and 10 in the foregoing table are not uncommon in New York state. There are at present two beet sugar factories in New York state, the one at Binghamton and the other at Rome.

The following are some additional analyses of limestones used in beet sugar manufacture. Nos. 1 and 2 of stone used at Los Alamitos (Cal.), and no. 3, a French stone.

No. 1, the Colton stone, is good. No. 2, Oro Grande, is passable. No. 3 is bad.

	1	2	3
Lime carbonate	98	94.306	81.67
Magnesium carbonate	.453	1.845	2.5
Iron and alumina oxid	1.096	.929	.27
Silica, sand, etc	.281	.9	8.2
Moisture	.051	.038	5.25
Organic matter and magnesium sulfate	......	.701	1.37
Undetermined	.116	1.281	.64

Lime is used in the cane sugar industry chiefly to effect neutralization of the acidity in the juices. "Lime is soluble in about 780 parts of water at 15° C and in 1500 parts at 100° C. Alcohol dissolves only a trace. Sugar water dissolves it in large quantity, whereby the lime enters into chemical combination with the sugar, forming sugar of lime. This fact is technically employed in separating sugar from molasses. The molasses is treated with lime, and the resulting sugar of lime is decomposed by the action of carbonic acid, forming calcium carbonate and pure sugar. Strontium has however lately displaced the lime in this process. 100 parts of cane sugar dissolved in water will dissolve 50–55 parts of lime."[1] I am informed by Dr F. G. Wiechmann that the lime used by the Brooklyn refineries is obtained from Glens Falls.

Chlorid of lime

Limestone which is to be used for this purpose must be very clean, for on this hangs the possibility of making strong and stable chlorid of lime. To satisfy these requirements the limestone must be sufficiently pure and thoroughly burned; consequently many manufacturers of lime chlorid purchase the limestone and burn it themselves. The burned lime should be free from carbonate of lime, and the limestone should have a minimum amount of sand, clay or similar impurities, which in burning do not turn into lime. Aluminous limestone clears with difficulty when dissolved, and hence is not liked by bleachers and paper manufacturers.

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[1] Frasch. Min. ind. 7: 495.

As the consumers require a pure white lime, the stone must contain practically no manganese or iron. These impurities are thought by some to also injure the stability of the lime chlorid, but this point is not definitely proved. The presence of magnesia is also undesirable, as the greater deliquescence of the magnesium chlorid renders the lime chlorid less stable. The presence of organic or bituminous substances in the limestone is entirely harmless, as they do little more than impart a dark color to the stone and pass off in burning.[1]

Fat limes which slake quickly and fall easily to a fine, light powder absorb chlorin much more quickly than lean limes, which on slaking give a sandy powder. In addition, chlorid of lime made from fat limes keeps much better than that made from lean limes.[2]

Carbon dioxid

A considerable amount of nearly pure dolomite has from time to time been shipped from the quarries at Pleasantville, Westchester co., for the manufacture of carbon dioxid. The stone was ground at the mines almost to the fineness of granulated sugar. From the grinder it passes into hoppers, whence it is fed automatically through tubes into barrels for shipment. The Quaternary marls near Caledonia have found favor for the same purpose, being utilized in Buffalo.

Soda manufacture

In soda-making by the Le Blanc process limestone is used to transform the sulfate of soda into caustic soda, the reaction being thus.

$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl$; $Na_2SO_4 + 2C = Na_2S + 2CO_2$; $Na_2S + CaCO_3 = Na_2CO_3 + CaS$.

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[1] Wagner. Chemische technische untersuchung's methoden. 1893. p. 430.
[2] Wright. C. R. A., Chem news, 16: 126.

Lithographing

Lithographic limestone is a somewhat impure, very fine and even grained limestone. It is not only rare but valuable. The requirements are sufficient porosity to absorb ink and softness enough to permit working with an engraver's tool. A very great degree of porosity is undesirable. The stone should also be free from cracks, or specks of impurities.

The chief supply thus far has come from Solenhofen, Bavaria and southern France. It has been reported from various localities in this country but never from New York state.

Lime

When limestone is burned, that is when it is raised to a red heat, it is dissociated into lime oxid and carbonic acid thus.

$CaCO_3$	$=$	CaO	$+$	CO_2
limestone or lime carbonate		lime oxid quick lime caustic lime		carbonic acid gas carbon dioxid

The carbonic acid gas passes off and the oxid of lime remains behind as a powdery or lumpy substance, which is often white, but may be more or less colored if iron is present.

As limestone varies in composition, the lime will also, but the percentage of impurities in the lime will be nearly twice what they were in the limestone, for the latter has lost 44% of carbonic acid gas.

Pure limestone consists of 56% of oxid of lime (CaO) and 44% of carbonic acid. The change from carbonate of lime to oxid of lime occurs during the burning, the carbonic acid being driven off at a higher temperature, and in this process the lime loses about 44% by weight; but, as it is generally in a somewhat moist condition when it is put into the kiln, due to water in its pores, the loss in weight may be still greater than that mentioned above. The percentage of moisture in limestone is very variable and depends largely on the hardness and density of the rock. The denser a limestone the less porous it will be and the lower will be the percentage of quarry moisture in it; while the looser or more spongy it is, the more moisture will it absorb. Marl and chalk may be looked on as the loosest forms of limestone, and in them the moisture may reach 36% or 40%. In marls and bituminous limestones the loss in burning will of course be much greater than 44%, owing to the contained water and bitumen. A dense limestone is much harder to burn than an open-textured one, and requires more fuel, but this increased consumption is more than made up for by the quality of the lime obtained. In a clean, dense limestone the percentage of quicklime may be 54% while in an impure one it may amount to only 30% or 35%.

In addition to the decrease in weight in burning, the limestone also decreases somewhat in volume, as much as 12% to 21%, but usually 16% to 18%.[1]

In burning it is important to observe that the temperature remains as constant as possible and varies only between certain limits; for, when limestone is overburned, the lime made from it slakes slowly and incompletely. In lime rock with clayey impurities a sintering is very apt to occur and this should in all cases be strictly avoided; but it is true that the higher the temperature within the permissible limits the denser will be the lime. On the other hand, the temperature must not get too low, as in this case any large pieces of limestone that may be in the kiln will not become thoroughly burned. The unburned core resulting from underburning makes the lime lean, and, to avoid such an occurrence as far as possible, it is advisable not to put too large pieces into the kiln.

The quicker such lime is burnt at the highest temperature possible the more readily it slakes, and therefore a slow burning process is disadvantageous.

Many different types of lime rocks are available for the manufacture of lime, those only being excluded which are contaminated with clay; for this latter substance often affects their most important properties, and it is only since the beginning of this century that the special application of limestone with a large amount of clay has been recognized.

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[1] Schoch, C. Die moderne aufbereitung und wertung der mörtel-materialien, p. 57.

The lime made from pure or nearly pure limestone is sometimes called air lime in contradistinction to hydraulic lime made from aluminous or clayey limestones.

Burning lime.[1] "The time required depends on the density and size of the lumps of stone and also on the moisture content; for water aids to a certain extent in carrying off the carbon dioxid. It is stated that in the presence of steam limestone can be burned in one eighth the time required in dry air and the gases of combustion. This accounts for the fact that stone freshly quarried can be burned faster; it has not yet lost its quarry moisture. Periodical injections of steam or water into the kiln are recommended by some, but are not always necessary in the case of flame kilns."

Limestone which is burned too slowly will make lime of inferior quality and will slake more slowly.

Limestone begins to lose its carbonic acid gas at 750° F, but it does not entirely pass off till the temperature of 1300° or 1400° F is reached. Limestone should never be burned with a coal running high in sulfur, as the latter unites readily with the lime, forming calcium sulfate. This sulfate of lime reacts subsequently with the aid of moisture on any alkalis that may be present, with the formation of alkaline sulfates, which being soluble, are often brought to the surface after the lime is in the wall, forming thus the unsightly white coating that is sometimes seen on bricks. This coating may also be at times caused by the presence of soluble sulfates in the clay.

Limekilns. The kilns used for burning lime bear more or less similarity to each other, the general principle of construction being that of a cylindric chamber, lined with fire brick, open at the top and tapering below to a discharge opening.

Limekilns are either continuous or intermittent in their action.

In the latter the stone is put into the kiln with alternate layers of fuel till the kiln is full. The fire is lighted, and the mass

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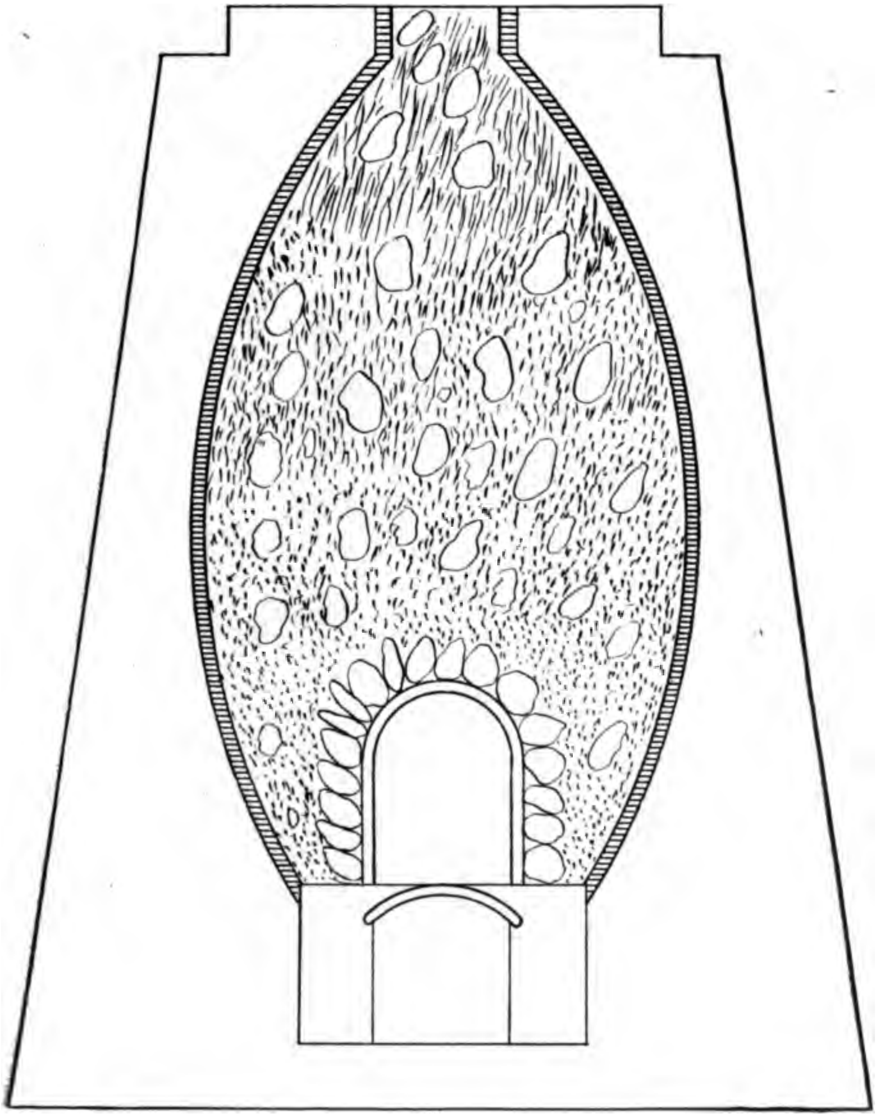
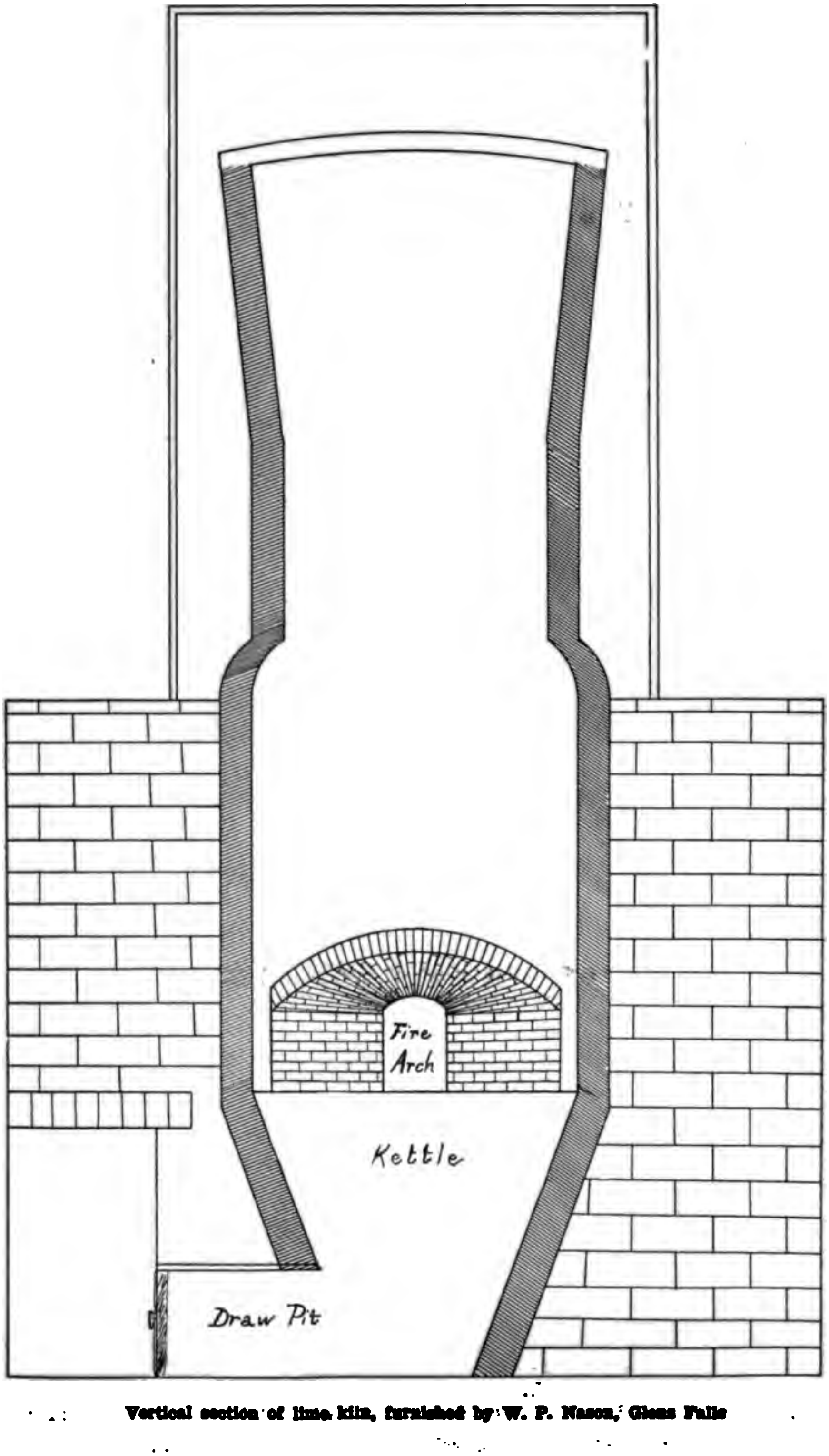
[1] Frasch. Min. ind. 7: 483.

Plate 3



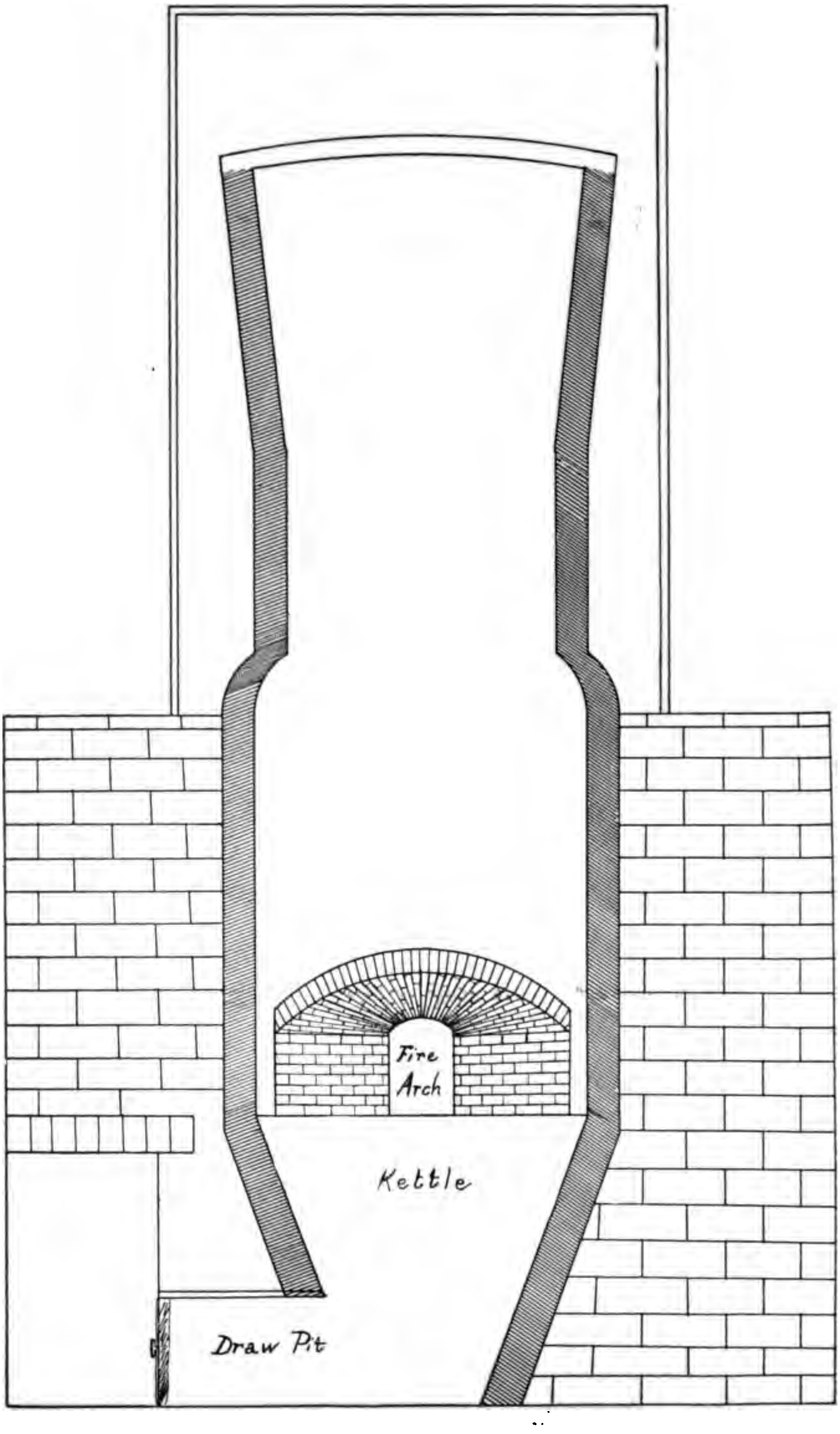
Section of lime kiln, after Gilmore

Plate 5



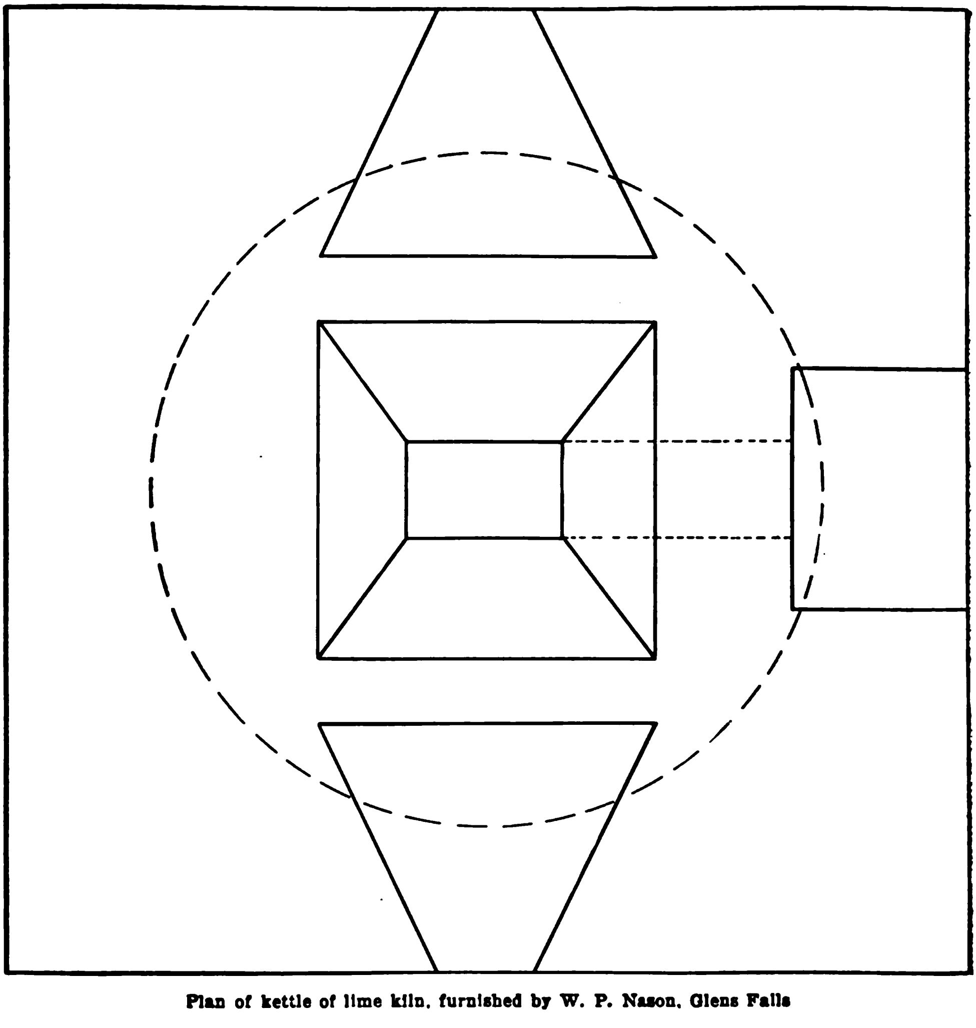
Vertical section of lime kiln, furnished by W. P. Nason, Glens Falls

Plate 5



Vertical section of lime kiln, furnished by W. P. Nason, Glens Falls

Plate 6



Plan of kettle of lime kiln, furnished by W. P. Nason, Glens Falls allowed to burn itself out, after which the burned stone is drawn off at the bottom of the kiln. The principle of such a kiln is bad, because it necessitates a mixture of the stone and the fuel, whose ashes may dirty the lime (pl. 3).

In the continuous kilns, the fuel does not come in contact with the stone; for fireplaces are built in the sides of the kiln several feet above the bottom. These fireplaces are arched openings, which extend from the exterior to the interior of the kiln. Into these the fuel is put, and burned, thus permitting the flames to pass upward through the stone, but preventing the ash of the fuel from coming in contact with it.

The older forms of kilns were massive stone structures, with thick walls, and having the chamber lined with one or two layers of fire brick. The more modern ones are circular in form, with much thinner walls, and bound with sheet iron plates.

In the accompanying plates are shown several forms of limekilns (pl. 4, 5, 6).

The lime obtained by the burning of limestone is a white, amorphous, more or less dense mass, with a specific gravity of 3.09. It is infusible. Lime weighs from 1400 to 1800 pounds to the cubic meter, the variation in weight depending on the density of the original rock and the degree to which it has been burned. Denser stone gives a denser lime.

Impurities. "Limestone containing silica and alumina should not be burned at too high a temperature, because of the sintering that takes place on the outside of the lumps and thereby interferes with the escape of the carbonic acid, yielding dead burnt lime, which does not slake completely.

It is said that dead burnt lime is more apt to be formed if the impurities are evenly diffused in the stone. The ashes of the fuel and also the alkalis in the stone may cause dead burning.

The best limestone, if heated too quickly but not long enough, may give dead burnt lime, in which case a basic calcium carbonate is formed, which with water forms a mixture of calcium carbonate and calcium hydrate and hardens.[1]

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[1] Frasch. Min. ind. 7: 483.

More than 10% of magnesia makes the lime short, and 25% to 30%, it is asserted, renders the stone unfit for burning;" nevertheless, such stone is burned in the southeastern part of New York state.

10% of silica, it is maintained, gives the lime hydraulic properties.

Frasch also states that limestone of 95% purity yields 59% burnt lime with 90% calcium oxid; of 90% purity, gives 60% burnt lime with 80% CaO; 85% stone gives 65.5% with 72% CaO, and 80% stone gives 70% with 64% CaO.

Slaking. Lime in its normal condition and when dry is totally unaffected by carbonic acid gas but when heated takes it up rather quickly. The addition of water to lime can be done in a variety of ways according to the degree of slaking that is to be brought about. If a lump of quicklime is immersed in water for an instant it saturates itself at once, and this absorption is accompanied by the evolution of heat and a swelling and bursting of the lime, which finally falls to a fine powder, the hydrate of the lime, $Ca(OH)_2$. The chemical action which has taken place is expressed by the formula $CaO + H_2O = Ca(OH)_2$.

This method of hydration is considered to be better than pouring the water on the lime.

The hydrate of lime thus obtained is a fine, white powder of a specific gravity of 2.1. Its water of hydration is pretty firmly combined and is only driven off by reheating to redness.

Fat limes slake very fast and produce more heat than lean ones, and lime will slake even in the air by the absorption of moisture, so that, if not used immediately, it should be protected from the atmosphere as much as possible.

Lime may also be slaked by putting the lumps in water for a few minutes, then withdrawing and packing away to allow the lime to change to powder. The common method usually employed in building operations is to mix the lime with water in a box. Too much water makes it thin and injures its cohesive strength. If only a part of the water required is added at first and the rest later, the lime becomes granular and lumpy. An excess of water in slaking is also undesirable, as it tends to lower the temperature of the mixture, and it is therefore well to use hot water if this can be done conveniently.

The hydration of lime powder or slaking to a pasty mass must be carried out very carefully, as otherwise, specially in the case of overburned lime, some unslaked particles will remain, which may slake later and make themselves unpleasantly prominent.

As water is added to the lime, it gradually forms a stiff paste, whose stiffness increases with the purity of the lime.

With careful slaking, 1 cubic meter of fat lime gives 2.7 cubic meters of paste and 1 cubic meter of lean lime gives 1.8 cubic meters.[1]

The excess of water is gotten rid of in part by evaporation and is also drawn off, while the slaked, pasty mass is allowed to stand in the pit to insure thorough slaking of every particle.

In the pits lime will hold itself for a long time without change provided it is properly protected from the air, but the damp lime paste absorbs carbonic acid greedily with the formation of carbonate of lime, which solidifies. The crust of calcium carbonate which forms is very thin, but it prevents the action from continuing farther in the mass. The solidifying action of the lime alone is of little importance and becomes of value only when sand is added. The use of the sand prevents large masses or lumps of the lime from collecting in any one spot and not becoming thoroughly converted into the carbonate.

Quicklime is a strong base and absorbs water with the greatest avidity, and in water it forms a milky liquid known as milk of lime.

On the other hand, quicklime can be made by adding the lumps of lime piece by piece to the water till a strong paste is formed by stirring the mass. The stirring is specially necessary in the case of lean limes.

In order to assist the slaking of such lean limes, it has been found advisable to use only one third the necessary amount of water at first and add the other two thirds later on. Again, as the lean lime gives out much less heat, it is well to keep the mixing pan covered in order to prevent its escaping. Lean lime also slakes better if a certain amount of fat lime is worked in with it. The latter has a sort of contact effect on the former, which is effective and rapid, so that this method is a good one to follow in using overburned lime.

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[1] Schoch, C. Die moderne aufbereitung und wertung der mörtel-materialien, p. 59.

Depending on the amount and nature of the impurities present, Gilmore divides natural and artificial limes suitable for mortar into five classes.[1]

"1 Common or fat limes
2 Poor or meager limes
3 Hydraulic limes
4 Hydraulic cements
5 Natural pozzuolanas

The common or fat limes contain less than 10% impurities, and a part of the latter are insoluble in water, all the rest of the lime being soluble. They do not harden under water but crumble or slake and increase in volume sometimes threefold. They shrink in hardening, and to prevent this sand must be added.

Poor or meager limes have from 10% to 25% of impurities, or sometimes even 39%.

Hydraulic limes are of three kinds:

a Slightly hydraulic ones with 10% to 20% of impurities
b Hydraulic limes with 17% to 24% impurities
c Eminently hydraulic limes with 20% to 35% of impurities[2]

All hydraulic limes harden under water. Hydraulic cement is an artificial product. It has less lime than the other classes, but not under 29%.

Natural pozzuolanas are rocks of igneous origin. They possess hydraulicity and generally under 10% of lime.

It is of course possible to find all intermediate grades between limes and cements.

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[1] Gilmore. Limes, hydraulic cements and mortars, p. 69.
[2] " " p. 71.

USES OF LIME

Basic steel

In the basic or Thomas and Gilchrist process the furnace or bessemer converter is lined with some basic material (that is material containing little or no silica), such as magnesite or dolomite. In this country the latter specially is used. Two things are required of the dolomite, viz, it should contain as high a percentage of magnesia as possible, and it should not have over 1½% or 2% of total fluxing impurities. It is specially important that the silica percentage shall be low, viz, under ½% if possible, for at high temperatures the lime or magnesia will eagerly unite with any silica present, and, as this action is equivalent to corrosion of the lining, any additional percentage of silica will materially affect the life of it. Pure dolomites are rare and when found are not always in easily accessible localities, but in this state two different bodies of nearly pure dolomite are known, the one at Ossining and Tuckahoe, Westchester co., the other at Rochester, Monroe co.

For use the dolomite is first burned to the sintering point and then ground and mixed with tar or other material to hold it together and permit molding.

The lime used in basic bessemer converters likewise has to be of great purity, and the stone must be of such a nature that it will burn to a lumpy and not a powdery lime; for, if the lime were added to the converter in the form of powder, the strong blast would quickly eject a large portion of it.

Refractory bricks

It is well known that oxid of lime is very refractory, a familiar illustration of this fact being the lime pencils used in the oxy-hydrogen blow pipe. Consequently lime is often used for lining the bottom of the hearth in a reverberatory furnace used for the manufacture of basic steel by the Siemens-Martin process. The lime serves to extract the phosphorus from the iron, and a high phosphorus slag is formed which is known as the Thomas phosphate.

Ammonium sulfate

In the manufacture of aqua ammoniae from ammonium sulfate lime is used to form sulfate of lime and thus liberate the ammonia, sufficient quantity being required to convert all the sulfuric acid in the sulfate and about one third more.

The lime is added in nearly every instance in the form of milk of lime, caustic of lime being employed in rare cases with a view to utilizing the heat evolved during the slaking, as in the Solvay process. This is not to be recommended, however, owing to the uncertainty which exists as to the time required by the lime to slake; for, if the latter is slow slaking, a temporary shortage of lime results, followed by a momentary excessive reaction, and, if any stoppage of the apparatus occurs, explosion may, and indeed at times does, result.[1]

The lime milk should be free from unslaked particles or sand grains, and magnesia is undesirable from the fact that it retards the distillation if ammonium chlorid or sulfate is present in the gas liquor, since it forms a double salt with them which can not be decomposed except at high concentration.

Contents of 1 liter of lime milk

Degrees Baumé	1 liter weighs grams	Lime grams	Water grams	Per cent lime
10	1 258.6	133.3	1 125.3	10.6
15	1 345	179.7	1 165.3	13.2
20	1 436	224.3	1 211.7	15.68
25	1 478	258.3	1 219.7	17.52
30	1 490	276.7	1 213.8	18.67
35	1 495.4	289.1	1 206.3	19.43
40	1 499	297.9	1 201.1	19.88
45	1 501.2	303.7	1 197.5	20.22
50	1 503.2	308.3	1 194.9	20.48
55	1 504.6	311.9	1 192.7	20.7
60	1 505.8	314.7	1 191.1	20.89
65	1 507	317.2	1 189.8	21.05

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[1] Frasch. Min. ind. 7: 45.

Milk of lime

Frasch states that the slaking of lime is mostly done in wooden boxes. For industrial purposes, where the lime is used in the form of milk, as in the distillation of ammonia, mechanical devices are employed for this purpose. The amount of lime present in milk of lime of different density is given in the above table from page 496, vol. 7 of *Mineral industry.*

Soap

In the manufacture of soap slaked lime is mixed with carbonate of soda to produce caustic soda. The two are mixed with water, and boiled with steam, the resulting carbonate of lime being separated by settling.[1]

Lime is also used in the manufacture of soft soap, in that the pearlash of commerce is converted into caustic potash by means of fresh lime. In the manufacture of stearin for candles ordinary tallow is boiled in wooden vats by high pressure steam with slaked lime for several hours, by which lime soap is formed. This is transferred to another vessel and treated with dilute sulfuric acid, which in combining with the lime forms a sulfate, which deposits while the fatty acids rise to the surface.[2]

In the manufacture of ball soda or black ash, salt cake, limestone and coal are mixed together in a reverberatory furnace. The limestone is sometimes soft and chalk-like. Good limestone should have 98% of carbonate of lime.[3]

Palm oils and tallow are the two chief fats bleached by the soapmaker. The color of the latter is sometimes removed by boiling it in lead-lined tanks with a solution of chlorid of lime.

In the saponification of tallow the latter is mixed with good slaked lime into a thin cream with water. This is then inclosed in a suitable vessel, and the whole boiled with steam and agitated for three hours. The action of the lime on the tallow decomposes it, glycerin being set free, while calcium stearate and oleate are formed. The formation of these salts, when mixed together, constitutes an insoluble soap, which is technically called rock, and facilitates the subsequent separation of the solid and liquid constituents of the tallow.

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[1] Watt. Art of soap-making, p. 128.
[2] " " p. 84.
[3] " " p. 109.

Tanning

In tanning lime is used to remove the hair from the hides, this being done in what are known as lime pits.

Bone-ash

In bone-ash manufacture the lime is employed to precipitate the substances dissolved out of the bones by hydrochloric acid, a fertilizer being obtained as a by-product and known as precipitated phosphate of lime.

Gas manufacture[1]

Lime is sometimes used in the purification of gas from hydrogen sulfid and carbonic acid gas. It can also be used to remove the carbon disulfid when special methods are employed. The lime is prepared in the ordinary manner and converted into hydrate by slaking. In order to get the lime in a fit condition for use however, it should be slaked two or three days before its use, for, if used as soon as formed, it is liable to cake in the purifiers and thus prevent the free passage of the gas through it. Before being placed in the purifiers, it is moistened with water till it attains such a consistency that, when pressed together in the hand, it will pack like snow. It is placed in the purifiers in 4 to 6 inch layers. The removal of CO_2 involves the formation of $CaCO_3$, and when H_2S is extracted, CaS, H_2S is formed. Both reactions may go on at once, but the lime has stronger affinity for the CO_2 than the H_2S.

In gas manufacture lime may be also used to form ammonia from ammonium chlorid or from ammonium carbonate contained in the gas water from the gas works, the reaction being $AmCl + Ca(OH)_2 = 2NH_3 + CaCl_2 + 2H_2O$.

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[1] Hornby, J. Gas manufacture, p. 117.

Potassium dichromate

Lime is used in the manufacture of this material, as one of the ingredients of the mixture containing chrome ore, alkaline salts and fuel. The materials are finely ground, mixed and roasted in a furnace, the object of the lime being to prevent fusion and aid in the formation of insoluble chromates. The lime used for this purpose has to be very finely ground to facilitate slaking, and it should furthermore be as free from silica and magnesia as possible.[1]

Paper manufacture[2]

Lime is used in the manufacture of paper to boil the rags in, the object being to get rid of the remaining dirt in them, and also to decompose some glutinous substances, which if allowed to remain would injure the flexibility of the fiber. The quantity of lime employed varies according to its composition and the condition of the rags, but ranges from 5 to 15 pounds to the 100 pounds of rags.

Agricultural uses

Lime is a very beneficial ingredient of the soil, if it is in a condition to be taken up by the plants, that is in a soluble form. Many soils may contain it in the form of silicate, as in feldspar, but till the mineral containing it has decomposed the lime does not become available. Some soils contain sufficient lime for the use of the plants, but in the case of others it has to be added artificially either as an ingredient of manufactured fertilizers or in the form of quicklime.

If the lime is present in the soil in the form of carbonate of lime, it can be detected by the effervescence produced on adding weak acid to the soil. The quantity of lime present in the soil naturally depends on the composition of the parent mass from which the soil was derived, and the climate, whether dry or moist; soils in the former tending to have a much higher percentage of lime, because they have been subjected to less leaching action by rainfall.

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[1] Frasch. Min. ind. 4: 101.

[2] Davis, C. T. Paper manufacture.

The advantages of lime agriculturally are great, its effect being both chemical and physical. Physically its action is to cause the soil particles to flocculate, that is to gather together and form compound grains, thus promoting the drainage of the soil, aerating it, and also making it more easily worked. Chemically it serves to hasten decay of the organic matter in the soil as well as that of the mineral particles, and thereby indirectly to facilitate the change of any iron compounds from a ferrous to a ferric condition. It also serves as plant food.

While lime has a stimulating effect on the soil, at the same time it tends to drain it of nourishment more rapidly than would otherwise be the case. The percentage of lime required to produce desirable results in a soil is said to be very small, those with only 1% of the carbonate being often productive.

Pottery glazes

In pottery manufacture lime is used in two different directions: viz in the manufacture of the pottery body, serving as a flux, and as a constituent of the glaze.

Minor uses

Other uses of lime are, for purifying drinking water; as a disinfectant; as a polishing material; for preserving eggs; in dyeing; in the manufacture of calcium carbid; for dehydrating alcohol; in the manufacture of lime pencils for oxyhydrogen lights.

Mortar

Mortar is a mixture of slaked lime and sand used for the purpose of binding masonry together, and more lime is probably used for this purpose than for any other.

The use of lime as a mortar has been known for many years, and the ancients were familiar with the fact that by means of simply burning limestone and soaking the burnt mass in water they could obtain a stiff paste which possessed valuable properties.

Pure lime has 71.4% calcium and 28.6% oxygen. It is a porous, earthy, white solid, which when pure resists a high degree of heat. It absorbs both moisture and carbonic acid from the air with the greatest avidity.

Richardson gives the following requirements for caustic lime when used for mortar.[1]

Except when made from coarsely crystalline marble or from marl or shells it should be in hard lumps.

It should be white, or nearly so, in color. Lime of a yellow or brownish color with veins of silicious matter is inferior.

It should be free from fused or semi-fused stone which shows over-burning, and from unburnt ash of fuel or clinker.

It should contain less than 10% of impurities but often has more.

It should slake rapidly, showing that it is rich and fresh.

Good lime in lumps should weigh, as packed, with about 40% of voids, 60 lb a cubic foot, 75 lb a bushel, and from 220 to 230 lb per 3 bushels. If ground or in powder, it will weigh less when packed loosely, but when well shaken down it will weigh as much as 270 lb a bbl. A lump of hard lime one foot cube would weigh about 95 lb, having a density of 1.52.

Slaking

Lime combines with water with evolution of heat and every 100 parts of lime takes 32 parts of water. If 33% of its weight in water is sprinkled on lime it heats, cracks open and falls to powder.

The increase in volume in slaking is caused by the expansive force of the steam, but lime may be slaked without increasing its volume by passing dry steam over it in a tube. The energy of slaking increases with the decrease of impurities. The same lime may show a varying increase in volume in slaking due to amount of water added, etc. The slow addition of water raises less heat, and slaking lime in an open box gives less heat than in a closed one.

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[1] Brickbuilder. 1897. p. 78.

With an equal volume of water the increase in size of a rich lime is 2 to 2.4%. Richardson illustrates this point as follows:

Vol. of H_2O	Increase in volume
½	1.6
1	2
2½	2.5
With a poor dolomitic lime it was	
2	1.7

No set rule can therefore be laid down. For instance, 1 peck lump lime with 44% of voids, on slaking with its own volume of water, gave 2¼ pecks of fine powder of slaked lime. From 1 peck of closely packed lime, 2.5 vol. of slaked lime were obtained.

Gilmore found large increases, some running 2.46, 2.83, 3.21, 2.40, but this was caused by his using larger amounts of water than are generally taken in practice.

The following table gives the tests made by both Gilmore and Richardson.

	Rockland	Rondout	New York
	Gilmore		Richardson
Weight of lime in pounds	5	5	5
Vol. of lime in cubic centimeters..	1 557	1 806	2 350
Vol. of water required	2 983	3 300	2 000
Increase of weight to slake, in %..	2.24	2.24	1.6
Increase in volume	2.46	2.14	1.91

The theoretic increase is 1.53. Lime also slakes simply on exposure to the air, but this is not good for mortar-making, as the slaking has not been accompanied by any violent disengagement of heat to rupture the mass. The larger particles also have a hardened rim.

Method of slaking

The water may be sprinkled over the lime gradually, or added at once in excess.

The former is best, because a looser mass is obtained, and it gives better results with poorer limes, slaking them more thoroughly. Too great an excess of water tends to lower the temperature and render the slaking incomplete. This causes unslaked particles to get into mortar, and by their subsequent slow hydration and expansion they may do much harm. Popping of mortar is due to this cause. It is also true that, if the water is added gradually, it may allow the mass to cool down. Enough water should be added to allow for that escaping as steam. With very fat lime 2½ vol. of water may be taken. Poor magnesian limes take less.

Pure water should be used. That with soluble salts gives rise to efflorescence, and hence sea water is undesirable, though it has been successfully tried for hydraulic cement. An excess of water gives granular paste and also makes the mortar porous.

After slaking sand is added to the lime to make mortar. According to Gilmore[1] the lime forms silicate, carbonate and hydrate, and the crystals of these compounds interlock with the sand grains, thus binding the whole together into a solid mass. In the course of time all the lime changes to carbonate, but this change may take a number of years.

Sand is added to lime for economy and to prevent shrinkage. Sand should be clean and sharp and should be in such quantity that the lime will fill all the interstices. If an excess of sand is used, the bond is poor. If too little sand is used, the mortar shrinks and cracks. If too little lime is used the paste is made thin. In ordinary sands, the spaces form 30% to 40% of the total volume, and in such 1 vol. paste fills voids of 2½ vol. sand.[2] In practice 1.25 to 2 vol. of sand to 1 of paste is used. This in case of fat lime means 3 to 5 vol. of sand to 1 measured vol. of lime. This gives a plastic mortar which does not crack.

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[1] Gilmore. Limes, hydraulic cements and mortars, p. 299.

[2] Brickbuilder. 1897. p. 101.

Richardson gives the following mortar experiments.

Composition and physical properties of the lime

Loss on ignition, H_2O and S	1
Insol. SiO_2 and silicates	1.2
Al_2O_3 and Fe_2O_3	.8
MgO	.6
CaO	95.6
	99.2
Weight of cubic feet including voids	60 lb
Voids	44%
Density of lump	1.52

	1	2	3	4	5
Weight of CaO used	1000	1000	1000	1000	1000
Weight of H_2O to slake	1000	2000	2500	3000	4000
Weight of H_2O for paste	1000	500	......	......	....
Vol. of H_2O to one of CaO	2	2.5	2.5	3	4
Vol. of paste	2000	2560	2712	3120	4120
Weight of paste	2720	3280	3392	3880	4850
Density of paste	1.36	1.28	1.25	1.24	1.17
Characteristics of paste	Thick	Thick	Medium	Thin	Very thin
Vol. of sand, moist	2000	3000	5000	7100	14360
Weight of sand	3000	4500	7500	10800	20600
Vol. of sand to lime	2	3	5	7.1	14.4
Vol. of sand to paste	1	1.2	1.8	2.6	3.5
Vol. of mortar	3320	4400	5840	7200	13500
Weight of mortar	5740	7760	10650	13960	25450
Density of mortar	1.73	1.75	1.82	1.94	1.88
Consistency of mortar	Thick	Medium	Medium	Sloppy	Very sloppy
Dries	Cracks	Dries without shrinking			

Percentage composition

Water	30	29.3	22.5	20.7	15.1
Sand	52.6	67.9	68.1	72.2	82
Lime	17.4	12.8	9.4	7.1	3.9
	100	100	100	100	100
Return of water to lime	1.7	2.3	2.4	2.9	3.9

CEMENT

The name cement was formerly applied only to materials which were added to lime mortar in order to make it harden under water. Subsequently this term was used for all combined material which gave a mortar that hardened under water, and so has extended to our natural and Portland cement. Under cement materials are now included hydraulic agents, hydraulic limes, slag cements, natural cements and Portland cements. Hydraulic agents are materials which cause silica and clay to unite with the lime of common mortar, giving us a combination of slow hardening properties. Such hydraulic agents may be natural or they may be artificial. The natural ones are represented by the pozzuolana of Italy, and the trass of the Rhine valley in Germany. In this country they are only known in the far west. The artificial hydraulic agents include slag, burned clay, shales, ashes, silicate of soda or any inorganic material that contains clay and silica in a form permitting its solution in acids.

When the clayey impurities increase in ordinary quicklime, it assumes hydraulic properties and the lime is known as hydraulic. Sand is an impurity which is not too large to prevent slaking but simply retards it. Hydraulic limes with only 5% to 15% of silicates will harden in from eight to 20 days, but with a larger amount in from one to four days. No sharp line can be drawn between true cements and hydraulic limes.

For convenience the following classification is made in this report.

Hydraulic limes
Rosendale cement, or natural rock cement
Portland cement

Hydraulic limes

These generally have 18% to 25% of clay, free silica and combined silica, iron oxid and alumina, sometimes magnesia and alkalis.

The burning of hydraulic lime must be carried on very slowly. The higher the percentage of total silicates, the lower must be the temperature of burning, for under no circumstances should the material be allowed to sinter as it does in the case of Portland cement. Such overburned pieces slake very slowly. Furthermore, the burning should only go to the point of driving off the CO_2. The best hydraulic lime known is the celebrated Chaux du Teil whose composition according to Dr Michaelis is:

Silica	22.588
Alumina	2.629
Iron oxid	.837
Lime	65.624
Magnesia	1.536
Potash	.124
Soda	.065
Sulfuric acid	.523
Ignition	6.424

Hydraulic limes have generally a yellow color. Their specific gravity is about 2.9 and on ignition they lose about 8%. They harden slowly and their hardness by themselves is small. On the other hand if mixed with sand they develop a high degree of tensile strength.

Natural or Rosendale cements

Under this heading are included those made from limestones which have over 20% of aluminous impurities, and which, when burned and finely ground, harden with water in a short time. This includes the Roman cements used abroad, and also the dolomitic cements made from magnesian limestones. They do not develop much heat on mixing with water, and their strength does not equal the artificial or Portland cement. They differ from hydraulic limes in their quicker set, and lower percentage of lime. The following anaylses given by U. Cummings[1] indicate the wide range of materials included under this class. Some authors in fact make two groups of the dolomitic and Roman cement materials, which they regard as coequal with Portland. The name, Rosendale, is often given to these cements, because it is the name of the locality at which the natural rock cement beds were first discovered and are best developed in the United States.

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[1] American cements, p. 35.

Analyses

No.	Silica	Alumina	Iron oxid	Lime	Magnesia	Alkalis	Lime sulfa'e	Loss on ignition	
1	16.05	1.92	3.22	77.29	1.52	....	....	....	Hydraulic limes Put in for comparison.
2	24.33	3.73	....	71.91	....	....	....	....	
3	23.71	5.85	3.29	59.53	.95	1.17	....	....	
4	20.57	1.13	....	77.76	.54	....	....	...	
5	23.14	9.1	3.2	58.34	1	2.8	....	2.42	
6	27.88	6.19	4.64	56.45	4.81	....	....	....	
7	25.31	7.03	9.74	56.17	1.75	....	....	....	
8	44.5	15	12	8.8	4.7	5.5	....	9.5	
9	48.94	18.75	11.92	6.4	2.42	3.93	....	7.64	
10	21.3	2.61	6.2	39.45	6.16	5.3	....	15.23	
11	34.66	5.1	1	30.24	18	6.16	....	4.84	
12	23.16	6.33	1.71	36.08	20.38	5.27	....	7.07	
13	26.4	6.28	1	45.22	9	4.24	....	7.86	
14	25.28	7.85	1.43	44.65	9.5	4.25	....	7.04	
15	30.5	6.84	2.42	34.38	18	3.98	....	3.78	
16	29.98	6.83	2.5	33.23	17.8	7.1	....	3.13	
17	30.84	7.75	2.11	34.49	17.77	4	....	3.04	
18	27.3	7.14	1.8	35.98	18	6.8	....	2.98	
19	27.98	7.28	1.7	37.59	15	7.96	....	2.49	
20	23.38	11.71	2.29	48.97	2.21	9	....	2.44	
21	19.9	5.93	1.14	46.75	16	8.02	....	2.27	
22	22.62	7.44	1.4	40.68	22	2.23	....	3.63	
23	26.69	7.21	1.3	43.12	19.55	1.13	....	1	
24	24.84	8.56	2.08	61.62	4	2	....	.8	
25	23.32	6.99	5.97	53.96	7.76	....	....	2	
26	27.6	10.6	.8	33.04	7.26	7.42	....	2	
27	33.42	10.04	6	32.79	9.59	.5	....	7.66	
28	22.58	7.23	3.35	48.18	15	....	....	3.66	
29	22.44	6.7	2	32.78	.67	....	....	35.46	
30	28.43	6.71	1.94	36.81	23.89	1.3	....	.92	
31	17.5	6.5	3	36.51	....	....	....	36.49	
32	22.21	16.48	1.67	39.64	17.5	....	....	2.5	
33	32.06	21.27	2.11	35.56	7	....	....	2	
34	2[illegible].45	2.24	2	5[illegible]	10	....	....	1.31	
35	18.59	9.14	1	40.7	27	....	....	3.57	
36	19.52	1.97	1.29	41.51	1.47	....	....	34.24	
37	28.02	10.2	8.8	41.48	1	.5	....	7	
38	25.15	8	3.23	49.58	13.78	....	....	.26	

SOURCE

1 Hydraulic lime, Aberthaw, Eng.; used in construction of Eddystone lighthouse

2 Hydraulic lime, Lyme Regis, Eng.

3 Eminently hydraulic lime, Holywell, Wales

4 Hydraulic lime, Le Teil, France

5 Hydraulic cement, "King's farm," Susquehanna river, near Williamsport, Pa.

6 Roman cement, Rüdersdorf, Ger.

7 Roman cement, Isle of Sheppy, Eng.

8 Pozzuolana, near Rome, Italy

9 Trass, from the Rhine valley
10 Buffalo hydraulic cement, Buffalo, N. Y.
11 Utica, Ill.
12 Milwaukee, Wis.
13 “Fern leaf” brand, Louisville, Ky.
14 “Hulme,” Louisville, Ky.
15 N. L. & C. co., Rosendale, N. Y.
16 “Rock lock” “
17 “N. Y. & R.” “
18 “Hoffman” “
19 Norton high falls “
20 Cumberland, Md.
21 Napanee, Ont.
22 “Newman,” Akron, N. Y.
23 “Cummings” “
24 South Riverside, Cal.
25 “Brockett,” Fort Scott hydraulic, Kansas City, Mo.
26 Utica brand, Utica, Ill.
27 Shepherdstown, W. Va.
28 Howard hydraulic cement, Cement, Ga.
29 Hydraulic cement rock on Platte river, Neb.
30 Mankato, Minn.
31 Cement rock, near Salt Lake City, U.
32 St Louis hydraulic cement, near E. Carondelet, Ill.
33 Barnesville, O.
34 Warnock, O.
35 Austin, Minn.
36 Blacksburg, S. C., cement rock.
37 Round Top cement, Hancock, Md.
38 Balcony Falls, Va.

The Rosendale region of New York is one of the best producers of natural cement (of the dolomitic type) in this country, but hydraulic limestone is found more or less in many states, specially those of the Appalachian region of the east. Others occur in the west and in the region of the Great lakes. Some idea may be gained of the extent of this industry at the present day by stating that the works for making natural hydraulic cements are found in New York, Pennsylvania, Maryland, Virginia, West Virginia, Ohio, Illinois, Kentucky, Minnesota, Kansas, Utah, New Mexico, Wisconsin and Texas. According to the United States geological survey, there were 76 plants in operation in 1899, which produced 9,868,179 barrels of natural cement, worth

$4,814,771. Nearly 50% of this was made in New York by 29 works. In fact it was in New York state that the first natural rock cement in this country was made, and the United States exceeds all other countries of the world in the quantity of natural cement produced.

The following table gives the production in 1899.

Production 1899

	No. of works	Product barrels (300 pounds)	Value
Florida (1898)	1	7 500	7 500
Georgia	1	13 000	9 750
Illinois	3	537 094	187 983
Indiana and Kentucky	19	2 922 453	1 022 858
Kansas	2	150 000	60 000
Maryland	4	362 000	144 800
Minnesota	2	113 986	56 793
New York	29	4 689 167	2 813 500
Ohio	3	34 557	17 279
Pennsylvania	5	511 404	255 702
Tennessee	1	10 000	8 000
Texas	1	12 000	20 400
Virginia	3	63 500	38 100
West Virginia	1	52 727	21 090
Wisconsin	1	396 291	151 992
	76	9 868 179	4 814 771

From the above it is seen that in 1899 natural rock cement was made in 16 states, by 76 firms.

Natural rock cement industry

The first in this country was made from waterlime rock in 1823, its nature being discovered by accident. It was found while the Delaware and Hudson canal was being put through Ulster county, and it was noticed that the lime which was burned from certain strata near Rosendale hardened under water instead of slaking. Similar discoveries followed rapidly at other localities, and as a result waterlime rock was found in western and central New York, in the Lehigh valley of Pennsylvania, in the James, Potomac, and Ohio river valleys, the result being that natural rock cements were made at all these localities at a comparatively early date.

In 1899 the total production of natural rock cement was 9,868,179 barrels. This was unequaled by any other country, the nearest approach to it being France, with six million to seven million barrels a year of both hydraulic lime and hydraulic cements. The United States is probably in the lead, owing to excellence and abundance of raw materials. The greatest production was in 1892; since then both product and price have decreased, one reason for this being the increase in the Portland cement industry.

The American natural cements are made from argillaceous limestone of varying geologic age. In western New York state they are mostly derived from the waterlime beds at the top of the Salina. Those of the Rosendale region are from the base of the lower Helderberg. In Wisconsin, natural rock cement is made from rocks of Devonian age near Milwaukee; and in Kentucky there is an important cement-producing area near Louisville. In Pennsylvania thick cement beds are found in the Trenton limestone of the Lehigh valley, but magnesian hydraulic limestones are also known in the Carboniferous. In Wisconsin cement rocks are quarried near Milwaukee, belonging to the Hamilton period. In Illinois near Utica and La Salle cement is obtained from the Calciferous limestone. The rocks of Maryland are also Silurian.

The deposits at Rosendale (N. Y.) are perhaps the most important; but those of the Lehigh valley in Pennsylvania are remarkable for their purity and extent.

The hydraulic limestones, or natural rock cements, can be divided into two classes based on the different amounts of carbonate of magnesia which they contain. In one class it does not exceed 3% or 4%, while in another 15% to 35% is found. Most of the hydraulic limestone of the United States is magnesian, but that found in the Lehigh valley and the upper Potomac is not. Likewise some of the deposits of the west; but it can be said in general that over 90% of the rock used is dolomitic. The Rosendale and the Louisville cements contain 15% to 25% of magnesia. The amount of the two carbonates in the two limestones varies from 54% to 75%, while the silica and the silicates may vary from 20% to 47%. The rock may even vary considerably in one locality, it being sometimes found that certain layers in a quarry make excellent cement, while others are useless or give a product of low grade. A good example of this is furnished by the following analyses quoted by Richardson in the *Brickbuilder*, 1897, p. 152.

Analyses

									Light	Dark		
	1	2	3	4	5	6	7	8	9	9	10	11
Loss on ignition...	36.56	29.5	41.95	34.82	31.09	39.65	23.55	33.23	37.34	39.64	30.94	38.95
Silica	14.61	23.99	6.68	15.97	21.45	9.89	33.06	20.47	15.01	9.06	19.7	8.01
Alumina and iron												
Insoluble	3.83	5.6	2.03	4.54	4.01	2.77	3.26	5.09	3.22	4.84	4.84	2.63
Soluble	2.49	4.17	1.58	3.05	2.86	2.73	3.26	2.67	5.22	2.51	5.09	1.89
Lime	25.25	20.16	31.59	23.72	23.87	28.63	20.33	26.2	25.85	27.88	20.25	39.77
Magnesia	16.18	13.33	15.81	15.64	12.93	15.15	10.26	11.59	18.84	15.67	15.23	7.43
Sulfur as SO2......	.78	1.29	trace	.71	.22	.34	.82	.58	trace	.38	.34	.44
Lime carbonate...	45.09	36.01	56.42	42.36	42.63	51.13	36.31	46.79	46.17	49.79	36.16	71.04
Magnesium carbonate..........	33.98	27.99	33.2	32.84	27.26	31.82	21.55	24.34	39.56	32.91	31.98	15.6
Total carbonate...	79.07	64	89.62	75.2	69.89	82.95	57.86	71.13	85.73	82.7	68.14	86.63
Silica etc., coarser than 100 mesh....	9.51	6.92	1.29	.04	......	4.84	.32	1.31	.32	......	2.02	.33

Mr Richardson states as follows:

It was recommended that stratum 1 be rejected, as it contained 9.5% of sand coarser than would pass through an ordinary screen of 100 meshes to the inch. This rock is also too rich in carbonates and would have given, under the best handling, an inferior cement, as magnesium cements deficient in clay are not constant in volume after use.

Stratum 2 had an excellent chemical composition but physically was too coarse, and, lying among inferior strata, it would naturally be rejected for economic reasons.

Stratum 3 was rejected because quite deficient in clay and silica.

Stratum 4 was characterized as a poor rock, which might be used if necessary, but was not recommended, being deficient in clay.

Stratum 5 was marked as being a slight improvement over 4, owing to the smaller amount of carbonates it contained, though deficient in clay.

Stratum 6 was too rich in carbonates and too low in alumina, or clay, to be used for hydraulic cement.

Stratum 7 was the most silicious of the series, though it contained little clay. With care in burning it could be used, as the silica present was in a fine state of division. It is, however, not an entirely satisfactory rock.

Stratum 8 proved a good stone for this quarry.

Stratum 9, in both its light and dark forms, was, besides having great lack of uniformity, too rich in carbonates and deficient in insoluble matter. By itself this stratum would prove a poor one.

Stratum 10 was excellent and recommended for use.

Stratum 11 appeared at a glance to be insufficiently hydraulic and was excluded.

Of all these strata, for one or more reasons, only those numbered, 5, 8, and 10, were considered fairly good rock if burned by themselves. It was possible, however, to mix different strata and thereby obtain a mixture of the proper quality. No. 7 was consequently included, and the cement so prepared analyzed as follows:

Loss on ignition	8.29
Uncombined silica	16.3
Combined silica	13.5
Alumina and iron oxid	11.04
Lime	33.36
Magnesia	15.58
Sulfuric acid	.4
Alkalis	1.5

Another series of hydraulic limestones, which are lacking in magnesia however, are also quoted by Richardson in the article referred to.

These facts emphasize clearly the necessity of thoroughly testing the rock to be used, in advance. Adaptibility for cement depends on the amount of silica and silicates which it contains and also on the percentage of sulfur and alkalis. In addition, the silica should be combined with the alumina, and the rock should also be dense. The two classes of natural cement, viz the magnesian and the non-magnesian, differ distinctly in other properties. The magnesian cements do not heat on mixing and with water they set and strengthen slowly but in the end are as strong as the lime cements. They do not resist frost well when first used, and often careful preparations have a tendency to expand a year or two after use. The lime cements, even after being carefully manufactured, have a tendency when made into mortar to heat, on the one hand, when too rich in lime and, on the other hand, to bloat when too rich in silicates or overburned. They acquire strength rapidly, having nearly as great a tensile strength at the end of from one to 28 days as the magnesian cements. They resist frost better than the latter but are at times inferior, more brittle and crystalline, with a tendency to deteriorate in strength. The perfectly prepared and carefully made cements of this class are the best natural cements in the world. The Round Top cement of the Potomac valley is typical of the highest grade of the lime cements, as the numerous Rosendale brands are of the magnesian class.

Physical properties

Of primary importance is the density of the rock. A light rock does not burn well and may not give a cement of suitable volume, weight or density. The specific gravity at 78° F should not be below 2.7, and preferably be 2.8. Some stones used have a specific gravity of only 2.65, but they are inferior. The best rock is obtained from those portions of the quarry which are beyond the range of weathering. Richardson gives the following density for the Rosendale rock.

Nearest surface	
Light rock	2.83
Dark rock	2.849
Medium	
Light rock	2.815
Dark rock	2.841
Light rock	2.827
Dark rock	2.845

The Fort Scott (Kan.) rock which is nearer the surface has a density according to Mr Richardson of only 2.73, the Round Top rock, Maryland, is 2.731, the hydraulic limestone of Illinois is only 2.667 and does not produce as dense a cement. It is also desirable that the various ingredients of the rock should be as thoroughly mixed in as possible. If the sand is coarse or the clay in lumps or the carbonate in pockets by itself, the rock is not adapted for making cement. Generally mere inspection will supply information on this point, and the size of the particles can be determined by dissolving a weighed fragment in acid and determining the size and quantity of the insoluble particles of sand remaining. The residue of the Rosendale rock found at various depths is noted by Richardson as follows.

Per cent of residue on sieve 200 mesh, 100 mesh, and 50 mesh

Nearest surface			
Light rock	...	2.9	...
Dark rock	...	...	...
Medium			
Light rock	...	...	...
Dark rock	...	...	...
Deepest			
Light rock	.6	.6	.4
Dark rock	1.2	.5	.3

On treatment with acids, the rock retains its shape, but the clay is dissolved out, and the residue can then be broken down with the fingers. If a coarse rock must be used, the burning should be slow in order to give a combination between the lime and silica every possible chance to take place.

Manufacture

The process of manufacture of this class of cements is comparatively simple. The rock as it comes from the quarry is usually broken into lumps of head size before being charged into the kiln.

The kilns in use in New York state are similar to those used for burning lime (pl. 3). The old type kilns are made of stone, with the interior either round, oval or rectangular in cross-section, and lined with fire brick. They are open at the top, and taper at the bottom to an opening, through which the burned stone is discharged. When the material is not being drawn, this hole is sometimes kept covered by grate bars.

At Akron (N. Y.) the kilns have an interior area of 9 x 22 feet, or when round a diameter of 9 feet. The hight of all is 34 feet.

The more modern kilns are cylindric in shape, made of boiler iron. They are from 40–45 feet high and lined with fire brick.

In burning natural cement rock, the fire is first started with wood in the bottom of the kiln, and on this are spread alternating layers of coal and rock. The coal is of pea or chestnut size commonly. As the burned stone is drawn from the bottom, fresh stone and fuel are added at the top. The kilns are commonly built on a hillside, or where the ground is flat, five, six or more in a row, and in either case tracks are laid on the top to facilitate the delivery of the stone and fuel. The yield of these kilns is large, being from 50–120 barrels of cement[1] per ton of coal. Some patented forms with the Campbell grate, such as is used at Milwaukee, give more uniform product and also use less fuel (pl. 7).

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[1] Min. ind. 2: 104.

When the material is drawn from the bottom, it is commonly sorted into normally burned rock, overburned or clinkered material, and underburned stone. At some works the clinker is retained and treated separately; for, though it is of much greater hardness than the normally burned stone, and requires more powerful machinery to crush it, still it possesses a much higher tensile strength. Three works in this state pulverize this clinker and put it on the market under the name of Portland cement.

There is usually a track running along the base of the kilns, on which the cars are brought to receive the calcined stone. These cars are then run up to the grinding rooms, where the rock is reduced to powder. Several types of crushers and pulverizers are used, including Gates and Blake crushers, Steadman disintegrators, Sturtevant burstone and emery mills, Cummings pulverizers, etc.

The burned stone usually goes through a gradual process of reduction, necessitating the use of machines for coarse, medium and fine grinding, and the types used as well as their arrangement is slightly different at each works, as will be seen by reference to the description of the New York industry given in subsequent pages. In the natural cement trade there are several standards of weight per barrel, as follows: Rosendale, 300 pounds net; Pennsylvania, 280 pounds net in barrels, 200 pounds net in sacks; Western standard, 268 pounds net.[1]

The Sturtevant roll jaw crusher (pl. 8) contains two steel jaws with curved faces, pivoted at their lower end. The jaws are operated by means of a toggle joint. It is claimed that this crusher takes rocks of large size and reduces them at one operation to gravel and sand. A crusher with 6 x 16 jaws weighs 7 tons, and requires 10 horse power to run it. Its capacity is asserted to be 3 tons an hour of Portland clinker, when set to ¼ inch opening.

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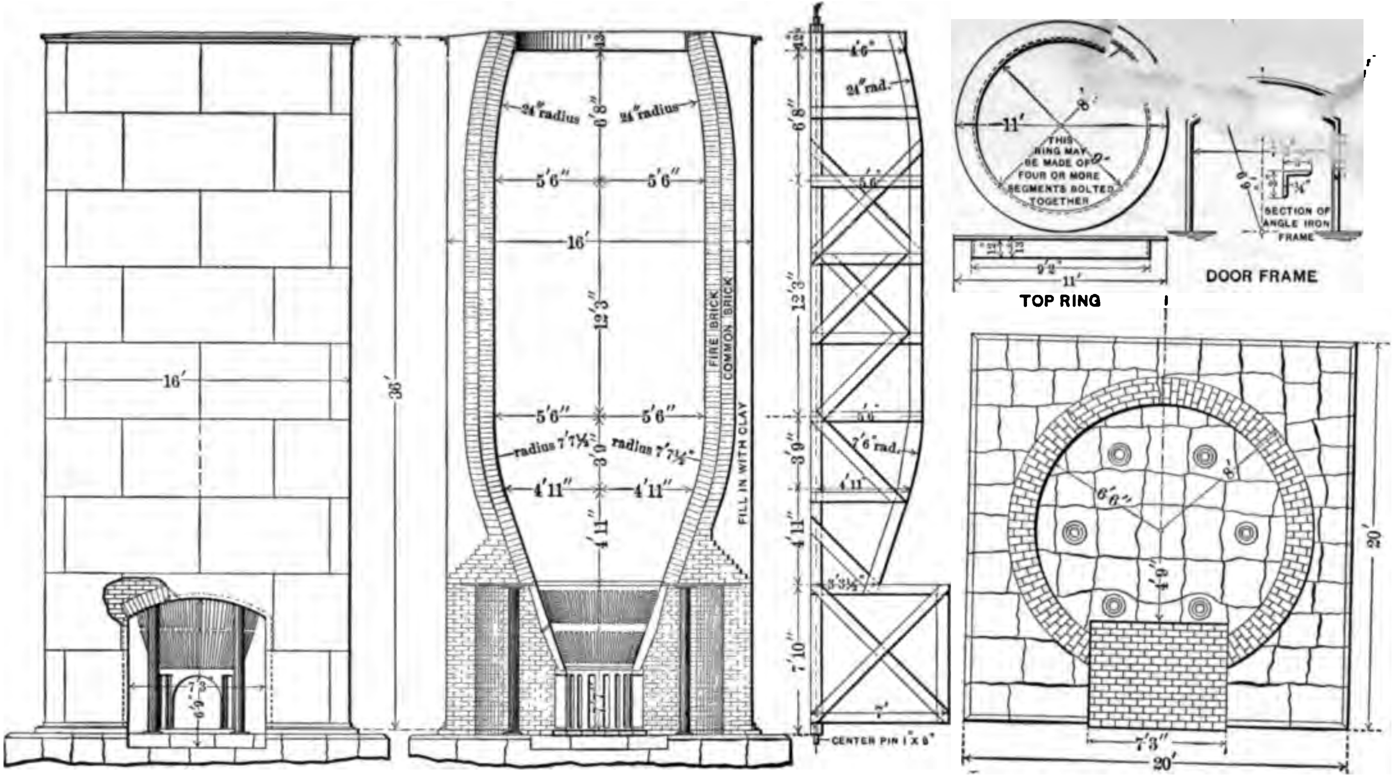
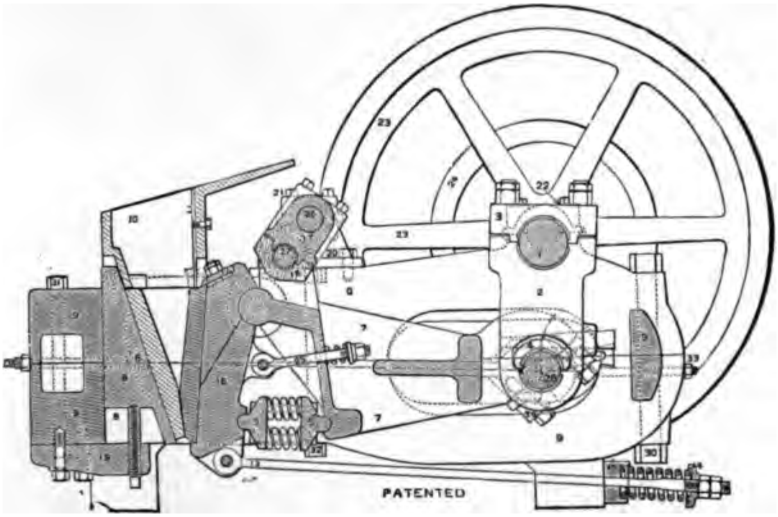
[1] Min. ind. 6: 104.



FRONT ELEVATION. SECTION. TEMPLATE. PLAN.

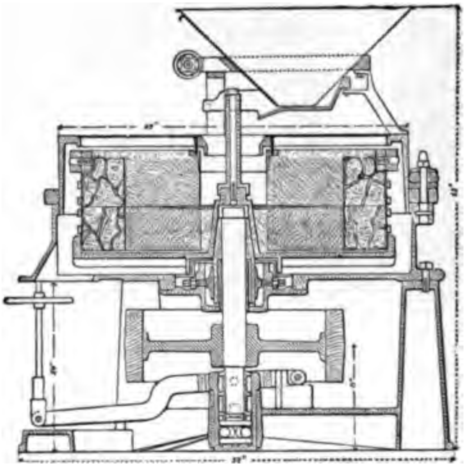
Kiln for burning natural rock cement, equipped with Campbell grate (Mineral industry, 6:106)

Plate 8 To face p. 688

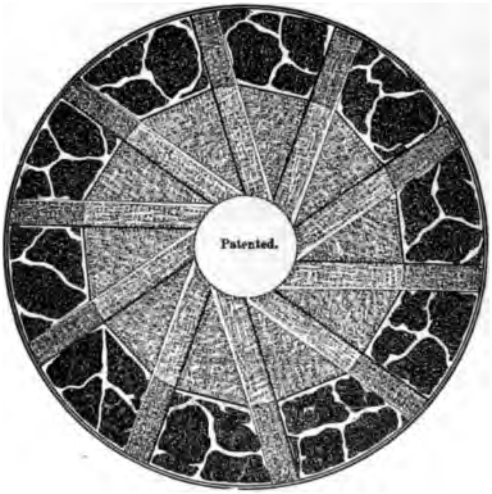


Vertical section of Sturtevant roll jaw crusher

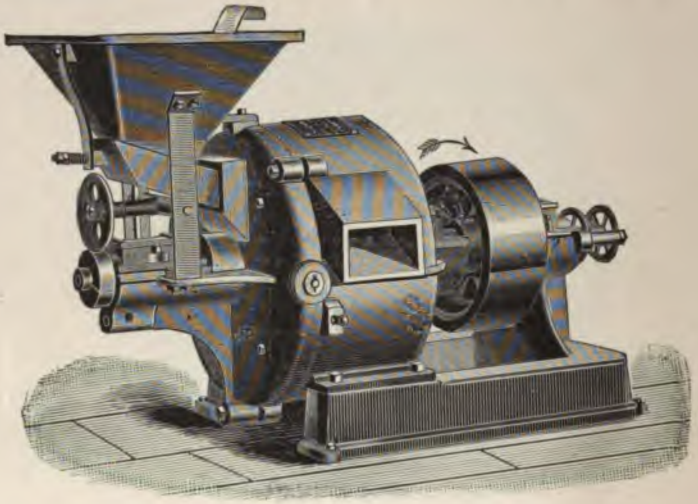
Plate 9 To face p. 689



Vertical section of Sturtevant emery mill



Sturtevant emery mill stone



Sturtevant disintegrator, used for grinding cement

The emery millstones of Sturtevant type are seen at many cement works. They consist of two millstones, with emery on the surface. The millstones are in each mill and are set in a horizontal plane. The bedstone is bolted in place, while the upper stone is set to revolve with the minimum amount of vibration. The lower stone is adjustable (pl. 9, 10).

The size of the mill is expressed in the diameter of the stone. The mills come in 36 and 42 inch size. A 42 inch size will grind on the average 5–6 barrels of Portland an hour, when working on crushed clinker. About 95% of the product from the millstones will pass a 100 mesh sieve.

The same machines grind from 18–20 barrels an hour of rock cement. These machines require from 15–18 horse power to operate them.

The Stedman disintegrator represents a type of mill in which the pulverization of the particles is produced by their being thrown violently against each other as the machine revolves. The machine which is shown in pl. 11, consists of several concentric drums, alternate ones revolving in the same direction, at a high rate of speed and represents a similar disintegrator of Sturtevant make.

These machines are said to be very efficient till the unequal wear of parts disturbs their balance, after which they deteriorate rapidly unless the worn parts are renewed.

Chemical composition

The amount of carbonate in each hydraulic limestone must not exceed 75% and preferably is under 70%, and, where the quarry contains several strata of different richness, it is possible to bring about the proper composition by mixing. Hydraulic limestones free from magnesia, it is claimed, give the best results provided they contain enough clay. The Maryland rock with 68.44% of lime carbonate and only 4.58% of magnesia, but with silica and clay amounting to 29.66%, is an example of this kind. In any single rock the amount of magnesia should not exceed

40% and should preferably be less than 25%. A stone with more than the latter amount has a tendency to expand slowly with age, specially if it runs low in clay. A western New York rock with 37% of carbonate of magnesia and less than 2% of silica and silicates is an example of this fact. The Rosendale cements contain only about 20% of magnesian carbonate with 30% of clay. The amount of silica and silicates present is highly important, for they influence the hydraulic properties of the limestone, and, as said before, the silica should be in combination with the alumina. This is determined partly from the quantity of alumina contained in the stone. For example, two stones, one from Akron (N. Y.) and the other from the Rosendale region, show according to Richardson respectively 35% and 29% of insoluble material; but, from the amount of alumina and iron present, we can see that there is very little clay in the Akron stone, while there is much of it in the Rosendale rock, the former having only 4.84% of alumina and iron, while the other has 10%. The Rosendale in consequence makes a very superior cement, while the Akron shows the qualities resulting from a deficiency in clay but an excess of magnesia. The effect of this deficiency in clay is to form a cement which heats and sets too quickly, but an excess of clay can also be injurious, as already stated.

Sulfur, when found in the limestone, is generally in the form of gypsum (sulfate of lime) or pyrites (iron sulfid) but both of these substances are seldom present in sufficient amounts to be injurious. They may occasionally become reduced in burning when combined with iron oxid to produce a green color. Alkalis such as potash and soda are harmless unless present in more than 2%; an excess of them makes the rock fusible, and such material has to be rejected. The following alkali percentages, in different natural rock cement, are given by Richardson.

Milwaukee, K_2O	.87
Milwaukee, Na_2O	1.64
Fort Scott, K_2O	.7
Fort Scott, Na_2O	1.33

Akron, Star, K_2O	1.39
Akron, Star, Na_2O	.23
Akron, Obelisk, K_2O	1.6
Akron, Obelisk, Na_2O	.52
Buffalo, K_2O	1.44
Buffalo, Na_2O.	.41

These alkalis are probably derived from feldspar grains in the clay.

Richardson makes the following subdivisions of natural cements, based on the examination of those made in various parts of the United States.[1]

1 Lime cement with only 2% or 3% of magnesia, 13% to 15% of iron and aluminum oxid, and 20% of combined silica.

2 Lime cements with as little magnesia but with less silicates than class 1, and consequently less satisfactory and more fiery.

3 Magnesia cements with a maximum of not more than 15% of magnesia, the same amount of iron and aluminum oxid and 15% to 20% of combined silica, and, in addition, considerable uncombined silicates, as they are not thoroughly burned.

4 Magnesia cement with a large amount of magnesia, viz over 20%, less alumina and iron and less undecomposed silicates than in the preceding class.

5 Magnesia cement deficient in alumina and iron oxids as well as in combined silica.

6 Magnesia cements thoroughly burned, made from rock having a smaller amount of silicates than those of class four, with only a medium per cent of magnesia and little uncombined silicates.

Cements of the first class set and acquire strength rapidly and increase in this direction for a long period, but the final result is a more brittle mortar than is obtained with the magnesia brands. This class includes the lime cements of the Potomac valley. According to Richardson, the second class has not as variable a relation of silicates to lime, and consequently the cements are apt to be fiery and not as satisfactory. They are shown to improve by the addition of Portland cement, after which they can be used quite successfully. This class includes those of the Lehigh valley. The third class is represented by the best Rosendale brands, which set and acquire strength slowly, but which continue to develop it for a long time and eventually are very strong and tough. The fourth class includes cements like those of western New York, which have been, while containing an unusual amount of magnesia, burned so hard that little of the silicates remains undecomposed and uncombined with the lime and magnesia, and in consequence they are apt to stand a long time after use, unless carefully hydrated. The fifth class is one in which the cement is essentially a lightly burned, highly magnesian material in the preparation of which the heat has not been sufficiently high or prolonged to bring the greater portion of the silica in composition with the lime or magnesia, in this respect being in contrast to the preceding class. The hydraulic principle and strength are therefore largely due to the magnesia and carbonates rather than to the silicates and aluminates. Examples of this are those cements made at La Salle (Ill.) The last class gives a cement in which there is rather less magnesia than in the two preceding classes, and less aluminum and iron oxid than in the third class. Though they are burned so thoroughly that there is but a small per cent of silicates uncombined, still, as Mr Richardson says, all of these cements will when properly burned and carefully handled give successful results in the large majority of cases. As a rule natural cement mortars will acquire a satisfactory strength with sufficient time, though it may have originally been very weak, or subjected to unfavorable influences due to the conditions under which it was used.

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[1] Brickbuilder. Jan. 1898. p. 14.

Portland cement

Portland cement is a hydraulic cement, in which the percentage of lime to alumina and silica is about as 2 to 1. It sets rapidly

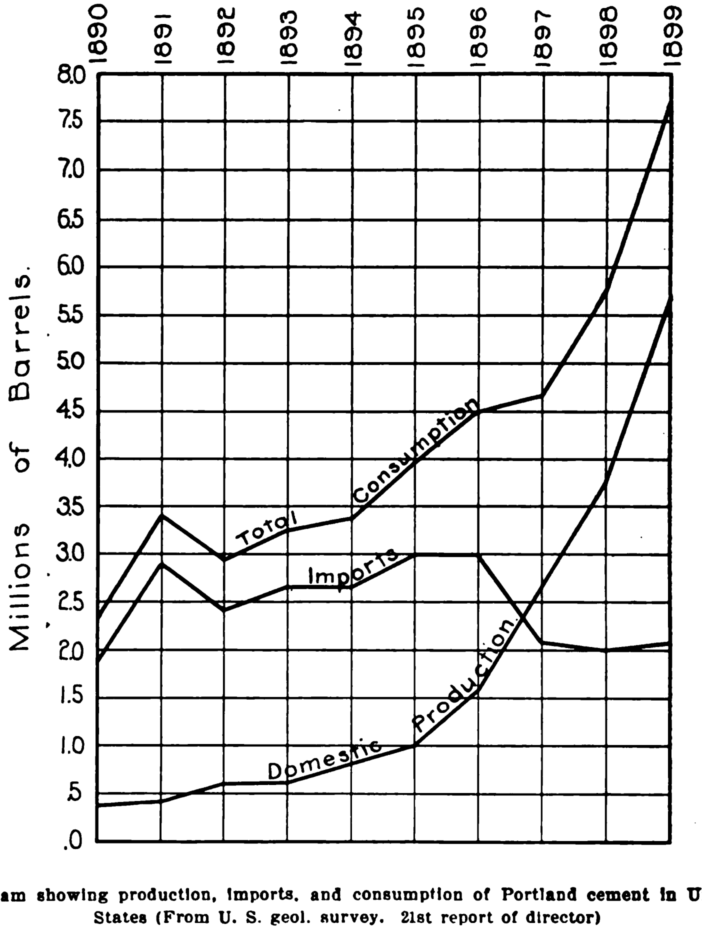

Diagram showing production, imports, and consumption of Portland cement in United States (From U. S. geol. survey. 21st report of director) as compared with hydraulic limes, and differs from the Rosendale type of cements in developing a much higher tensile strength, and being invariably very low in magnesia.

Portland cement was discovered by Joseph Apsdin, of Leeds (Eng.), who desired to make an artificial cement that would replace natural hydraulic cements. It received its name because it hardened under water to a mass resembling Portland stone. With very few exceptions, Portland cements are artificial mixtures, and many of the so-called "natural" Portland cements made in the United States and Germany are not strictly such.

The use of hydraulic cement is very old; still the Portland cement industry has been developed entirely in the present century. In this country it is widespread and active, but the output is not large enough to supply the home markets, for the growth of the Portland cement industry has been greatest abroad up to the last three or four years.

In England Portland cement is made chiefly in the Thames and Medway districts, where white and gray chalks and river mud are used. In Germany the Portland cement industry is developed chiefly in the northern part of the empire, the region about Stettin and the Rhine valley being important centers of production. In these localities the materials used are chiefly chalks and marls which are mixed with clay. In southern Germany and Austria as well as Switzerland hard limes are used, in northern France marls, chalks and clays are the materials employed.

The enormous development of the Portland cement industry in the United States, as well as the amount of material used, both native and foreign, may be judged from the following table, which gives the production of Portland cement in the United States from 1891 to 1898 inclusive and also the imports for these years. These imports include shipments from Germany, Belgium, France, England and Denmark.

The statistics are taken from the volume, *Mineral resources, 21st ann. rep't United States geol. sur.* (*see* pl. 12).

Production in United States

	1891	1893	1895	1896	1897	1898
Home production	454 818	590 652	990 324	1 543 023	2 667 775	3 692 284
Imports	2 983 818	2 674 149	2 997 395	2 989 597	2 090 594	2 013 818
Total	3 443 126	3 264 801	3 987 719	4 532 620	4 758 369	5 706 102
Exports	....	14 276	33 682	53 466	53 466	36 732

This shows that the total consumption has increased between 30% and 40%, and that this increase has been supplied mostly by American factories, the imports having remained nearly stationary. It will be noticed that in 1893 the United States also began to export some Portland cement.

Production by states 1899

State	Number of works	Product, barrels	Value not including packages
Arkansas	1	50 000	$87 500
California	1	60 000	120 000
Illinois	2	53 000	79 500
Indiana		None in 1899	
Maryland		"	
Michigan	4	342 566	513 849
New Jersey	2	892 167	1 338 250
New Mexico	1	1 500	4 500
New York	7	472 386	708 579
North Dakota	1	1 700	5 100
Ohio	6	480 982	721 473
Pennsylvania	9	3 217 965	4 290 620
South Dakota	1	35 000	70 000
Texas		None in 1899	
Utah	1	45 000	135 000
	36	5 652 266	$8 074 371

The uses of Portland cement are daily increasing, those now important including: concrete, for river improvement and canal work, culverts and bridge abutments, sidewalks, masonry. In this connection the following remarks of Prof. S. B. Newberry may be quoted.

American cements have largely replaced foreign brands throughout the U. S. This is especially true of English and Belgian cements, which are generally inferior to the best German brands. There is no difficulty whatever at present in selling a good American Portland cement in St Louis and Chicago at a higher price than any well-known English cement; nevertheless the fact remains that there is among contractors a considerable prejudice in favor of certain brands of German cements, and the latter still command a higher price than the American. This prejudice is unfounded, and is therefore certain to depart in time, but it still exists. American cements can be made at a price which will allow them to be sold cheaper than the best imported German, and, where the two come together in competition on large contracts, the work is generally made to the American manufacturers on the basis of price. This was clearly shown on the letting of a large government contract at Pittsburg last winter. The offers were as follows:

1	Belgian cement	$2.50	a barrel
5	German cements, average price....	$2.66	"
4	American cements, average price...	$2.28	"

The price of Portland cement is steadily coming down, and the fall is being hastened greatly by the successful competition of American against foreign manufacturers. There can be no doubt that with a very few years practically all the Portland cement consumed in this country will be of domestic manufacture. The prices of some brands, however, will hardly be the same as they are now. When the demand is completely supplied by American manufacturers, we shall have works in this country producing 2000 barrels per day more than in Germany, and the same result will be reached here as in Germany, namely the complete replacement of the common natural cement rock cements by artificial Portland.[1]

Portland cement industry

Portland cement was first manufactured experimentally in this country at Coplay, Lehigh co. Pa., in 1872 at a locality in which natural rock cement had up to that time been made. A second one was at Wampum, Lawrence co. Pa., where fossiliferous limestone and clay were used.

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[1] Newberry, S. B. Brickbuilder. 1897. p. 108.

According to Lewis[1] the principal Portland cement plants in operation in the United States in 1897 together with their dates of establishment were:

Company	Brand	Locality	Established
Coplay cem. co.	Saylors, Commercial	Coplay Pa.	1875
J. K. Shinn & Bro.	Wampum	Wampum Pa.	1876
Millen & Sons	Millen	South Bend Ind.	1877
Millen & Sons	Millen	Wayland N. Y.	1891
Amer. cem. co.	Giant and Egypt	Egypt Pa.	1884
Amer. cem. co.	Giant	Jordan N. Y.	1891
Emp. port. cem. co.	Empire	Warner N. Y.	1886
Atlas cem. co.	Atlas	Coplay Pa.	1889
Alpha port. cem. co.	Alpha	Whitaker N. J.	1891, [a]'94
West. port. cem. co.	Western	Yankton S. D.	1890
Buckeye cem. co.	Buckeye	Bellefontaine O.	1892
Sandusky cem. co.	Medusa	Sandusky O.	1893
Diam. port. cem. co.	Diamond	Middlebranch O.	1893, [a] '97
Bonneville cem. co.	Star	Siegfrieds Br. Pa.	1894
Vulcanite cem. co.	Vulcanite	Vulcanite N. J.	1895
Glens Falls cem. co.	Iron Clad	Glens Falls N. Y.	1895
Bronson port. cem. co.	Bronson	Bronson Mich.	1897
White Cliffs port. cem. co.	Setter	Whitecliff Ark.	1897

[a] Rebuilt.

Additional works have been started at Coldwater and Union City (Mich.), Smiths Landing (N. Y.), La Salle (Ill.), Litchfield (Ky.), and besides these there are several smaller ones. According to Mr Lewis the total capacity of the American works is about 3,000,000 barrels, of which 70% comes from the Lehigh valley region of western Pennsylvania and eastern New Jersey.

Composition of American Portland cements

The American Portland cements are made from a variety of materials which resemble each other chemically rather than geologically. As the cement is made from artificial mixtures, it is frequently possible to use many different grades of limestone and clay-bearing rocks. Though Portland cement is made at many places and from material of widely different character, Portland cement materials are not so very numerous. The alumina and silica are commonly supplied by clay, sometimes shale; and the lime carbonate from limestone or marl.

According to the United States geological survey,[2] the number of factories using limestone or marl is as follows.

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[1] Min. ind. 6: 94.

[2] 20th an. rep't. U. S. geol. sur. pt 6, p 545.

	1897		1898	
	No	Product, bbl.	No.	Product, bbl.
Factories using limestone...	18	2 282 126	20	3 112 492
Factories using marl	11	395 649	11	579 792
	29	2 677 775	31	3 692 284

The essential elements of Portland cement are calcium, silica and alumina. The first is generally supplied by limestones or marl, the two latter by clay. In burning these three elements unite to form silicates of a complex nature, and it is essential that they be combined in proper proportion in order to give the best results. Faija claims[1] that the lime may vary from 58% to 64%; the silica from 18% to 24%; the alumina and iron from 8% to 14%.

In rare instances it is possible to find a natural limestone which contains the three essential elements in the proper proportion. With marl the expense of crushing and grinding the material is saved, but both have their advantages as well as their disadvantages. The chemistry of Portland has been most carefully studied by S. B. and W. B. Newberry[2] who come to the following conclusions.

1 The essential constituents of Portland cement are tricalcic silicate with varying amounts of dicalcic aluminate. The composition is therefore expressed by the formula X $(3CaO,SiO_2)+$ Y $(2CaO,Al_2O_3)$. From this the proportion is calculated, that is, lime by weight $= 2.8\ SiO_2 + 1.1\ Al_2O_3$.

2 Fe_2O_3 combines with lime at a high heat and acts like the alumina in promoting the combination of the silica and calcium. For practical purposes the presence of ferric oxid in clay is not to be considered.

3 Alkalis, judging from the behavior of soda, are of no value in promoting the combination of calcium and silica and probably play no part in the formation of cement.

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[1] Trans. Am. soc. civ. eng. 30: 43.

[2] Cem. and eng. news. 1898. 4: 5.

4 Magnesia possesses strong hydraulic properties when ignited alone but has none when heated with silica, alumina and clay, and probably plays no part in the formation of cement. It will not replace lime in mixtures, the composition of which should be calculated on the basis of lime only, without regard to the magnesia present.

Using the formula previously given they made up and tested cements as shown below.[1]

	R. Ca to Silicates	CaO	SiO2	Al2O3	Pat. test	Hot test	Tens. str. ¼sq in. section 7 days	 28days
Silicate 95.8 Aluminate 4.2	2.67	72.79	25.21	2	Set hard, sound, on glass	Sound, off glass, hard	154	173
Silicate 91.6 Aluminate .4	2.57	71.9	24.1	4	Set hard, sound, on glass	Sound, off glass, hard	148	227
Silicate 85.3 Aluminate 14.7	2.39	70.55	22.45	7	Set hard, sound, off glass	Sound on glass	180	205
Silicate 74.8 Aluminate 25.2	2.15	68.31	19.69	12	Set quick, sound, off glass	Sound, on glass, hard	105	84

The actual composition of some leading cements on the market is given below.

Calcium silicates

Formula	R. Ca to SiA	CaO	SiO2	Pat. test.	Hot test
2 Ca SiO	1.85	65.11	34.89	Set hard, hard 7 days, hard 6 weeks	Sound, on glass, hard
2½CaO 1 SiO2	2.33	70	30	Set soft, fairly hard 7 days, hard 6 weeks	"
3 CaO SiO2	2.8	73.68	26.32	Set soft, fairly hard days, hard 6 weeks	"
3½CaO SiO2	3.27	76.56	23.44	Cracked soft 1 day, hard 6 weeks	"

Dr Michaelis considers that in good Portland cement the ratio of the total silicates to the lime should be about as one to two, and that the variation from this ratio should only be within narrow limits. Cements rich in lime set more slowly, but harden better than those poor in lime. Cements rich in silica generally set slower than those rich in alumina but the former harden very energetically in the beginning and are better for use under salt water. According to Dr Michaelis[2] the celebrated German Portland cement manufactured at Stettin in Germany has a silica percentage of nearly 25 with 5.7% of alumina and 2.5% of ferric oxid.

A material like the limestone of Teil is for instance admirably suited for the manufacture of Portland cement to be used in marine work; its composition is: silica 24; alumina 2.8; ferric oxid .9; lime 70.

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[1] Cem. and eng. news. 1897. v. 3, no. 6, p. 85.

[2] Schoch. Die moderne aufbereitung und wertung der mörtel-materialien, p. 85.

Schoch expresses the opposite opinion to Newberry, and considers that alkalis act as a flux, and they can be replaced by calcined soda. He also states that they are of great benefit in connection with the hardening process of cement, as they convert the silica into a soluble form, in which condition it combines with the lime when wet.

An addition of ⅛% to ¾% of fluorspar is very beneficial for bringing about an easy clinkering of the materials. Nearly all cements contain some magnesia and sulfur, which come originally either from the clay or from the fuel used. Redgrave[1] states that all mixtures containing 77% of carbonate of lime will, when sufficiently calcined, give Portland cement of fair quality. Compounds with too much clay fuse too easily, and the resulting cement is light in weight, sets quickly, has a brownish color and never becomes thoroughly hard.[2] It moreover crumbles when exposed to the weather. Overlimed cements, that is where the part made of lime in the slurry ranges above 77% or 78%, give a cement which will stand the hottest fire without fusing.

Such cements when burned are slow setting and hard to grind, and Portland cement made from such mixtures is liable to flow and swell.

In Europe the clay is generally mixed with marl or chalk, but in this country comparatively little marl is used. In this country Prof. S. B. Newberry[3] gives 17 works as mixing limestone with the clay, and seven using marl, and of the latter four are in New York state.

Marl is cheaper to use for the manufacture of Portland cement, as it is softer and finer grained and consequently needs little grinding. It always has a large percentage of moisture which must be expelled.

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[1] Redgrave. Calcareous cements.
[2] " p. 39.
[3] Mineral resources of U. S. 16th an. rep't U. S. geol. sur. 4: 545.

Redgrave gives the following analyses of English Portland cement mixtures.

1 Mixture made at Folkestone from gray chalk and gault clay

2 Forest of Dean limestone and clay

3 Mixture from Barrow lias quarries

All dried at 100° C, but 2 and 3 have perhaps also lost some H_2O.

	1	2	3
Sand	2.5	5.57	2.58
Silica	11.83	9.61	11.41
Ferric oxid	1.97	2.42	2.34
Alumina	5.23	3.45	4.8
Iron pyrites	tr.	.....	.43
$CaCO_3$	74.18	75.89	74.09
MgCO	1.29	1.5	2.61
$CaSO_3$	.18	.16	.21
K_2O	.9	.88	.93
Na_2O	.31	.39	.46
H_2O	1.82	.61	.43

A clay or Medway mud from Gillingham is as follows:

SiO_2	38.413	Sand
Al and Fe	1.856	
SiO_2	25.249	Hyd. silicates
Al_2O_3	14.244	
Fe_2O_3	6.744	
CaO	.81	
MgO	1.727	
K_2O	2.957	
Na_2O	.773	
H_2O	3.384	
Pyrite	.214	

The clay used for cement should not contain an excess of sand or iron. Clays low in iron are usually of a gray or blue color and light yellow on weathering. The clay should be fairly silicious, and the more amorphous silica present the better. Michaelis[1] gives the following typical examples.

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[1] Hydraulischer mörtel u. Portland-cemente, p. 99.

	1	2	3	4	5	6
SiO_2	60.06	59.25	60	62.48	68.45	54.72
Al_2O_3	17.79	23.12	22.22	20	11.64	24.27
Fe_2O_3	7.08	8.53	8.99	7.33	14.8	7.64
CaO	9.93	.....	4.18	6.3	.75	1.89
MgO	1.89	2.8	1.6	1.16	.....	.....
K_2O	2.5	1.87	1.49	1.74	1.9	.....
Na_2O	.73	1.6	.72	.87	2.1	.....
$CaSO_4$	.6	2.73	.89	.60	.....	.....

1 Province of Saxony
2 Vorpommern
3 Oberharz
4 Brandenburg
5 } Medway
6 }

In most of the European cements the lime runs from 60% to 65%, while in the American it seldom exceeds 63%. In the French and Belgian cements the sulfuric acid is low, in order that they may comply with the engineer's specifications. The Portland cements made in the eastern United States generally show more magnesia than the western ones. The maximum percentage of this material in American is about 4%, while in the European it is 2.5%. Magnesia was formerly considered very objectionable, but opinion is now receding on this point. Those American brands containing 4% of magnesia are not shown to be at all inferior.

In the various numbers of the *Thonindustrie zeitung* for 1897 and 1898, that is vol. 21 and 22, will be found a number of articles and discussions concerning the effect of magnesia in Portland cement. Elaborate experiments of R. Dyckerhoff abroad have not shown any injurious effects to come from 4% MgO. Many American manufacturers adulterate cement by adding sulfate of lime. This generally acts as a diluent, and it should always be stated when it is done.

The raw materials used in the manufacture of Portland cement may sometimes contain sulfate of lime in the form of the mineral gypsum, or sulfur may be present in the form of pyrite, which in burning tends to react with some of the carbonate of lime, yielding calcium sulfate. A similar effect may be caused if there is much sulfur in the fuel used. The effect of this sulfate of lime, if it does not exceed 2% or 3%, is to greatly delay the setting of the cement and also increase its final strength somewhat. If present to the extent of 4% or 5%, however, both these qualities disappear, since the formation of calcic sulfid is brought about, which in turn reacts with the iron compounds in the cement and tends to disintegrate it. The effect of sulfate of lime is shown in the accompanying table, taken from Prof. Johnson's work, *Materials of construction* (p. 187).

The German association of Portland cement manufacturers has declared against any addition except up to the 2% $CaSO_4$ to regulate setting time. It is the general practice in the United States now to put in 2% $CaSO_4$ to produce slow set.

The following experiments are quoted by Lewis, showing the effect of sulfate of lime on the rate of setting.[1]

NO.	ONE SORT OF CEMENT	SETTING TIME	NEAT-CEMENT BRIQUET					BRIQ. 1 CEMENT, 3 SAND				
			7 days	28 days	12 weeks	25 weeks	1 year	7 days	28 days	12 weeks	25 weeks	1 year
1	As manufactured	0° 20′	323	405	518	620	700	115	168	238	302	360
2	Same w. .5% gypsum	3° 30′	315	456	572	623	650	142	212	330	358	390
3	.1% "	10° 0′	375	508	568	695	780	159	238	311	368	384
4	.2% "	14° 0′	423	543	688	718	805	180	263	305	375	410
5	No gyp. but kept in store for some months	10° 30′	318	450	550	592	618	168	218	3 8	360	431

Results reported by John Grant in 1880.[2]

MIXTURE	7 days	31 days	60 days	90 days
1–1 briq. average of 5	107	159	188	267
1–1 briq. w. H_2SO_4 added to water; average of 5	129	227	260	255

Results reported by Prof. Tetmajer in 1894.[3]

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[1] Min. ind. 6: 101.

[2] " 6: 89, 90.

[3] Mitth. d. Aus zur Prüfung v. baumaterialien. 1894. 7 hfte, p. 89.

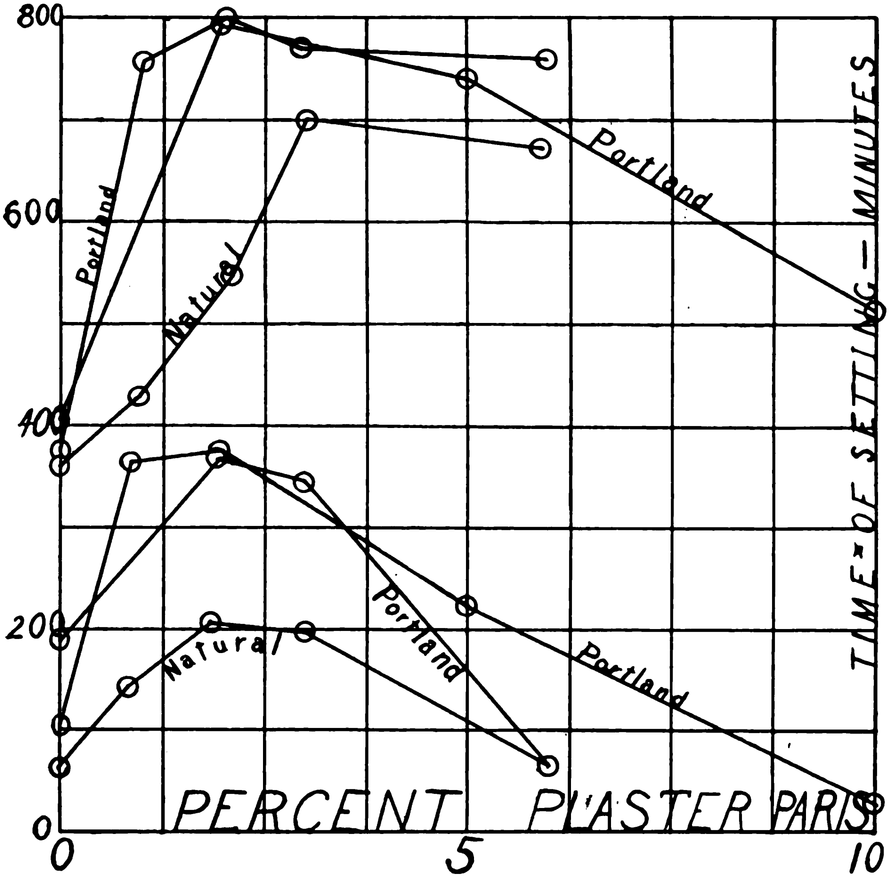

Diagram after Johnson, showing effect of lime sulfate on rate of setting of natural and Portland cement

MgO	SO_3	MgO	SO_3
.86	1.25	2.84	1.53
2.79	1.71	1.16	2.71
1.81	1.24	2.73	1.51
1.45	1.1	1.85	1.39
1.68	1.5	1.32	1.32
2.48	1.36		

American raw materials used in the manufacture of Portland cement also show a great variation in their composition, as will be seen from the following table of analyses taken in part from *Mineral industry,* 6: 97, and from the volumes on mineral resources in the annual reports of the director of United States geological survey.

Analyses of raw materials

	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	CaO	$MgCO_3$	MgO	$CaSO_4$	SO_3	Ins.	H_2O& Org.
Lehigh val. Pa. cem. rock	14.68	5.32	1.12	69.26	.....	3.67	.....	2.29	.....	.....	1.68*b*
Lehigh val. Pa. cem. rock	15.4	4.26	1.38	74.66	.....	2.66	.....	.86	....	.....	1.88*b*
Lehigh val. Pa limestone	5.87	1.59		88	.....	4	.....	......	.....	....	— *c*
Lehigh val. Pa cem. mixt	13.97	5.07	1.88	74.1	.....	2.04	.....	......	.....	.....	1.82*b*
Lawrence co. Pa. limes'ne	4.14	.21	1.77	90.47	.....	1	.....	......	.....	.....	2.03*b*
Warren co. N.J. cem. mixt.	14.16	6.64		73.96	..	3.13	.....	......	.....	.....	*c*
Glens Falls limestone	3.3	1.3		....	52.15	....	1.58	......	.3	*a*	8.37
Glens Falls clay	55.27	28.15		....	5.84	....	2.25	......	.12	.....	......
Warner marl	.26	.1		94.39	.....	.38	....	.....	.....	....	4.64*c*
Warner clay	40.48	20.95		25.8	.....	.99	.....		.....	....	8.50*c*
Sandusky marl	......	1.72		92.7	.....	.53	....	2.06	.....	1.28	1.13*c*
Sandusky clay	64.7	11.9	9.9	....	.9	....	.7	......	....	....	11.90*c*
Bronson marl	1.65	...	.81	90.66	.....	tr.	.....	......	.66	.....	5.59*c*
Bronson clay	62.1	20.09	7.81	......	.65	....	.96	......	.49	.....	7.90*c*
Yankton chalk	2.15	2.72		93.72	.....	....	.....	.....	.....	.....	*c*
Yankton chalk	8.2	7.07		83.59	.....	....	.....	......		.....	*c*
Yankton clay	57.98	18.26	4.57	.....	1.75	....	1.83	......	1.28	.....	12.08*c*
Arkansas chalk	4.42	2.21	1.03	95.29	.....	....	.....	...	....	.....	*d*
Arkansas chalk	6.09	3.52	1.2	87.93	.....	....	1.06	......	.....	.....	*d*
Arkansas clay	53.3	23.29	9.52	......	.36	....	1.49	......	....	.....	5.16*d*
Arkansas clay	65.12	19.05	7.66	....	.34	....	.31	......	.....	.....	6.12*d*
La Salle Ill. limestone	8.2	1.3		88.16	.....	1.78	....	....	.	.....	......
La Salle Ill. clay	54.3	19.33	5.57	....	3.29	......	2.57	......	2.36	.....	......
Litchfield Ky. limestone	.49	tr.	.22	97.63	...	.65	...	.....	.34	.....	......
Litchfield Ky. clay	55.82	19.77	6.19	....	.7	......	.....	....	.....	.....	....
Harpers O. marl	.....	1.15	....	82.66	.....	1.32	.....	.45	.....	7.28	6.54
Syracuse Ind. marl	......	1.21	....	88.49	...	2.71	.....	1.58	.....	1.78	4.23
Wellston O. limestone	3.53	1.14		....	54.45	....	.44	......	.....	38.74	*e*
Wellston O. clay	69.49	16.42		....	2.29	....	.78	......	.....	5.43	......

a CO_2 46.98. *b* Pa. geol. sur. *c* Mfr's anal. *d* Branner. Proc. Am. inst. mining. eng. *e* Loss on ign.

The following additional analyses are also taken from the *Mineral industry*, 6: 97 and 99.

European materials

	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	CaO	$MgCO_3$	MgO	Ins.	Ign.
English white chalk, from	.66	....	.33	98.6	......	.21	......	......	*a*
to	1 29	....	.74	97.9	......	.1	......	......	*a*
English gray chalk, from	1.67	.93	.38	96.5	......	.5	......	......	*a*
to	6.84	1.14	.45	87 85	......	.1	......	......	*a*
English cement slurry	11.77	4.45	2.13	69.97	......	2.87	......	1.24	7.59*a*
English cement slurry	11.83	5 23	1.97	74.18	......	1.29	......	2 53	1.82*b*
English Medway clay	63.66	16.1	6 74	....	.81	....	1 73	......	3.38*c*
English Tyne clay	55.83	23.04	7.78	....	......	2.57	......	......	*b*
								SO	
German Hamburg chalk	1.55	....	.5	97.5	......	....	.19	.2	*d*
German Hamburg clay	52.5	17.35	5.75	....	4.49	....	3.24	.91	14 *d*
German Stettin marl	19.7	3.66	1.34	73.92	......	.97	......	.32	*d*
German Stettin clay	54.6	18.2	5.4	....	2.8	....	3.16	.90	13.1 *d*
German Rhine limestone	3	.42	.53	94.5	...	....	.86	.13	*d*
German Rhine clay	60.7	19.13	8.37	... .	2.63	....	3.20	1.04	13.4 *d*
Belgian Beerse clay	65.5	18.55	6.01	... .	.38	....	1.18	.14	*e*
" Visé chalk	1.42	5.77		96.8	......	.45	......	......	*e*

American cements

BRAND	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	AUTHORITY
Alpha	22 62	8.76	2.66	61.46	2.92	1.53	Bootle, G. B.
Atlas	21.96	8.29	2.67	60.56	3.43	1.43	"
Giant	19.92	9.83	2.63	60.32	3.12	1.13	"
Saylors	22.68	6.71	2.35	62.3	3.14	1.88	"
Vulcanite	21.08	7 86	2.48	63.68	2.62	1.25	"
Empire	22.04	6.45	3.41	60.92	3.53	2.73	"
Jordan	21.46	7.17	3.73	61.14	2.34	1.94	"
Diamond	21.8	7.95	4.95	61.9	1.64	.79	"
Sandusky	23.08	6.16	2.9	62.38	1.21	1 66	"
Bronson	20.95	9.74	3.12	63.17	.75	.86	Mfr's. anal.
Whitecliffs	22.98	10.83		64.67	.94	1.05	"

a Heath. *b* Redgrave. *c* Stanger and Blount. *d* Candlot. *e* Michaelis.

MgO	SO_3	MgO	SO_3
.86	1.25	2.84	1.53
2.79	1.71	1.16	2.71
1.81	1.24	2.73	1.51
1.45	1.1	1.85	1.39
1.68	1.5	1.32	1.32
2.48	1.36		

American raw materials used in the manufacture of Portland cement also show a great variation in their composition, as will be seen from the following table of analyses taken in part from *Mineral industry,* 6: 97, and from the volumes on mineral resources in the annual reports of the director of United States geological survey.

Analyses of raw materials

	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	CaO	$MgCO_3$	MgO	$CaSO_4$	SO_3	Ins.	H_2O & Org.
Lehigh val. Pa. cem. rock	14.68	5.32	1.12	69.26	.....	3.67	.....	2.29	.....	.....	1.68*b*
Lehigh val. Pa. cem. rock	15.4	4.26	1.38	74.66	.....	2 66	.....	.86	.....	.....	1.88*b*
Lehigh val. Pa limestone	5.87	1.59		88	.....	4	.....	.....	.....	.....	— *c*
Lehigh val. Pa cem. mixt	13.97	5.07	1.88	74.1	.....	2.04	.....	.....	.....	.....	1.82*b*
Lawrence co. Pa. limes'ne	4.14	.21	1.77	90.47	.....	1	.....	.....	.....	.....	2.03*b*
Warren co. N. J. cem. mixt.	14.16	6.64		73.96	..	3.13	.....	.....	.....	.....	*c*
Glens Falls limestone...	3.3	1.3		.....	52.15	.....	1.58	.....	.3	*a*	8.37
Glens Falls clay.........	55.27	28.15		.....	5.84	.....	2.25	.....	.12	.....	.....
Warner marl	.26	.1		94.39	.....	.38	.....	.....	.....	.....	4.64*c*
Warner clay	40.48	20.95		25.8	.....	.90	.....		.....	.....	8.50*c*
Sandusky marl	.....	1.72		92.7	.....	.53	.....	2.06	.....	1 28	1.13*c*
Sandusky clay...........	64.7	11.9	9.9	.....	.9	.....	.7	.....	.....	.....	11.90*c*
Bronson marl	1.65	.....	.81	90.66	.....	tr.	.....	.....	.68	.....	5.59*c*
Bronson clay	62.1	20.09	7.81	.....	.65	.....	.96	.....	.49	.....	7.90*c*
Yankton chalk	2.15	2.72		93.72	.....	.....	.....	.....	.....	.....	*c*
Yankton chalk	8.2	7.07		83.59	.....	.....	.....	.....	.....	.....	*c*
Yankton clay	57.98	18.26	4.57	.....	1.75	.....	1.83	.....	1.28	.....	12.08*c*
Arkansas chalk	4.42	2.21	1.03	95 29	.....	.....	.....	.....	.....	.....	*d*
Arkansas chalk..........	6.09	3.52	1.2	87.93	.....	.....	1.06	.....	.....	.....	*d*
Arkansas clay...........	53.3	23.29	9.52	.....	.36	.....	1.49	.....	.....	.....	5.16*d*
Arkansas clay...........	65.12	19 05	7.66	.....	.34	.....	.31	.....	.....	.....	6.12*d*
La Salle Ill. limestone...	8.2	1.3		88.16	.....	1.78	.....	.....	.....	.....	.....
La Salle Ill. clay........	54.8	19.33	5.57	.....	3.29	.....	2.57	.....	2.36	.....	.....
Litchfield Ky. limestone	.49	tr.	.22	97.63	.....	.65	.....	.....	.34	.....	.....
Litchfield Ky. clay......	55.82	19.77	6.19	.....	.7	.....	.....	.....	.....	.....	.....
Harpers O. marl.........	.....	1.15	.....	82.66	.....	1.92	.....	.45	.....	7.28	6.54
Syracuse Ind. marl......	.....	1.21	.....	88.49	.....	2.71	.....	1.58	.....	1 78	4.23
Wellston O. limestone ..	3.53	1.14		.....	54.45	.....	.44	.....	.....	38.74	*e*
Wellston O. clay........	69.49	16.42		.....	2.29	.....	.78	.....	.....	5.43	.....

a CO_2 46.98. *b* Pa. geol. sur. *c* Mfr's anal. *d* Branner. Proc. Am. inst. mining. eng. *e* Loss on ign.

The following additional analyses are also taken from the *Mineral industry*, 6: 97 and 99.

European materials

	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	CaO	$MgCO_3$	MgO	Ins.	Ign.
English white chalk, from	.66	....	.85	98.6	......	.21	......	......	*a*
to	1.19	....	.74	97.9	......	.1	......	......	*a*
English gray chalk, from	1.67	.93	.88	96.5	......	.5	......	......	*a*
to	6.84	1.14	.45	87.85	......	.1	......	......	*a*
English cement slurry	11.77	4.45	2.13	69.97	......	2.87	......	1.24	7.59*a*
English cement slurry	11.83	5.23	1.97	74.18	......	1.29	......	2.53	1.82*b*
English Medway clay	63.66	16.1	6.74	....	.81	....	1.73	......	8.88*c*
English Tyne clay	55.83	23.04	7.78	....	......	2.57	......	......	*b*
								SO	
German Hamburg chalk	1.55	....	.5	97.5	......	....	.19	.2	*d*
German Hamburg clay	52.5	17.85	5.75	....	4.49	....	3.24	.91	14 *d*
German Stettin marl	19.7	3.66	1.34	73.92	......	.97	......	.32	*d*
German Stettin clay	54.6	18.2	5.4	....	2.8	....	3.16	.90	13.1 *d*
German Rhine limestone	3	.42	.53	94.5	...	....	.86	13	*d*
German Rhine clay	50.7	19.13	8.37	... .	2.63	....	3.20	64	13.4 *d*
Belgian Beerse clay	65.5	18.55	6.01	... .	.38	....	1.15	14	*e*
" Visé chalk	1.42	5.77		96.8	......	.45	......		*e*

American cements

BRAND	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	AUTHORITY
Alpha	22.62	8.76	2.66	61.46	2.92	1.53	Bootle, G. B.
Atlas	21.96	8.29	2.67	60.56	3.43	1.43	"
Giant	19.92	9.83	2.63	60.32	3.12	1.13	"
Saylors	22.68	6.71	2.35	62.3	3.14	1.88	"
Vulcanite	21.08	7.86	2.48	63.68	2.62	1.25	"
Empire	22.04	6.45	3.41	60.92	3.53	2.73	"
Jordan	21.86	7.17	3.73	61.14	2.34	1.94	"
Diamond	21.8	7.95	4.95	61.9	1.64	.79	"
Sandusky	23.08	6.16	2.9	62.38	1.21	1.66	"
Bronson	20.95	9.74	3.12	63.17	.75	.86	Mfr's. anal.
Whitecliffs	22.98	10.33		64.67	.94	1.05	"

a Heath. *b* Redgrave. *c* Stanger and Blount. *d* Candlot. *e* Michaelis.

European cements

BRAND	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	AUTHORITY
White label Alsen	20.48	7.23	3.88	64.3	1.76	2.46	B. G. B.
Dyckerhoff	20.61	7.15	3.69	63.06	2.33	1.39	"
Germania	22.08	6.84	3.36	63.72	1.32	1.82	"
Hemmoor	21.14	5.95	4.01	63.24	1.44	1.47	"
Lagerdorfer	23.45	7.47	2.4	61.99	1.42	1.07	"
Brook, Shoobridge co	22.2	7.35	4.77	61.46	1.35	1.87	"
Francis	22.18	8.48	5.08	61.44	1.34	1.56	"
Condor	23.87	6.91	2.27	64.49	1.04	.88	"
Candlot Fr	22.3	8.5	3.1	62.8	.45	.7	Candlot
Boulogne Fr	22.3	7	2.5	64.62	1.04	.75	"

Manufacture of Portland cement

The steps usually followed are preparation of the raw materials, mixing, burning, grinding and bolting.

In Portland cement manufacture there are two general methods of preparation, the aim of each being to mix thoroughly the raw materials. These methods are known as wet and dry methods. In the wet method proper the materials are mixed by forming them into a thin paste with water, after which they are dried before burning. In the dry method only enough water is used to permit forming the materials into bricks, so that they can be charged into the kiln. A modification of the dry method consists in grinding the material dry and charging it in this manner into the rotary furnace, or mixing only enough water to make it ball.

Wet process. The raw materials best adapted to this method are soft chalk and plastic clay, which on account of their condition can be easily mixed with water. The material has sometimes to be reduced to a powder by means of crushers, but this is not always necessary, and the mixing is done in water. It is the custom at some works to give the material a preliminary mixing by spreading it in alternating layers of chalk and clay on the floor, and, when it is removed to the washing mill, digging into it vertically.

The wash mills in which the mixing is done consist of several different forms, but they are essentially cylindric tanks, sometimes of masonry, at others of wood, the usual diameter being 20 feet and the depth 6 feet to 7 feet. In the center of the tank is a masonry pier, which supports a revolving vertical shaft, which carries the wooden frame with the scrapers. This is driven by means of a rack and pinion. Such a mill makes about 20 revolutions a minute, and sometimes the materials are put through twice in succession to insure a thorough mixing, enough water being added to keep the whole in suspension. If the water has to be evaporated, then it is best to use as little as possible. Water is continually added during the stirring, and, as it overflows, it passes off through chutes to the backs. These chutes also serve the purpose of arresting any sand that the material may contain.

One of the disadvantages is that, owing to differences in specific gravity of the clay and chalk, they may settle with different rapidity. This can be guarded against by repeated testings. It is claimed by some[1] that the wet process does not mix the materials as thoroughly as the dry method, specially where limestone is used.

Another disadvantage is the time required to dry, and also the floor space needed.

Dry method. In this method the raw materials are ground dry separately, after which they are mixed, and then wet up to a paste known as slurry, which is molded into slabs or bricks to facilitate charging it into the kiln. This method of preparation may be used in connection with any type of kiln except the rotary one, for in this case there is no need of forming the slurry into cakes of any kind. At some works a dry press instead of a stiff mud machine is used to mold the bricks.

Burning. After the raw materials have been thoroughly mixed they are burned to a condition of incipient vitrification. According to the type of kiln used, the mixture is charged in either the wet or dry condition. The changes which take place in burning are of great importance, for on their proper manipulation depends the quality of the manufactured product. These changes are three in number, i. e. driving off of the mechanically combined water; driving off the carbonic acid; fusing together of the silica, alumina, lime and iron. Each of these requires a different temperature for its accomplishment, but the attainment of the proper temperature to produce the last change is the most important. If the required temperature is overstepped, the cement is overburned and has little or no setting power.

---

[1] Gary, M. Trans. Am. soc. civ. eng. 1893. 30: 3.

Specific gravity. The specific gravity of the Portland cement is often an indication of the thoroughness of the burning, and is determinable by some form of pycnometer.

One type consists of a flask with a stopper, and having a long graduated neck. The vessel is filled with benzin or turpentine up to the zero graduation on the tube. A given weight of cement is dropped into the tube, care being taken to allow all the air bubbles to escape, when the rise of the liquid in the tube indicates the volume of cement added. If metric units have been used, then the specific gravity of the cement is equal to the weight of the quantity added in grams divided by the increase in volume in cubic centimeters.

Well burned Portland cement has a specific gravity of more than 3.05, but should not exceed 3.15 or 3.20.

In making this test it is necessary to see that there are no lumps, and that the cement is thoroughly dried.

Kilns. The types of kilns used in the United States are: intermittent or dome kilns; continuous kilns, of Dietzsch or Shöfer type; rotary furnace.

In the old-fashioned intermittent kiln the bricks of cement and coke are charged in alternate layers. The Dietzsch and Shöfer kilns are continuous, as already stated, and possess the great advantages of cheaper fuel, economy of labor, and of burning the dry, powdered material. The rotary furnace effects an enormous saving of time and labor, and it is claimed that the temperature can be regulated far more exactly than is possible in

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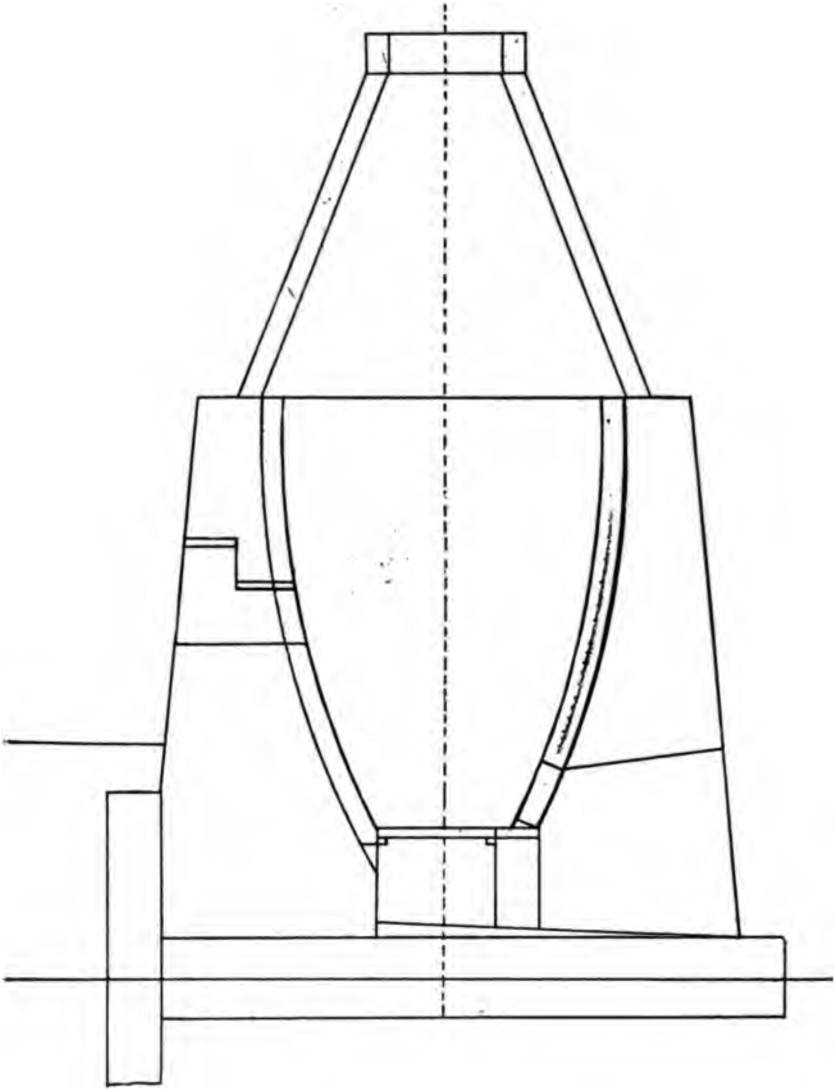
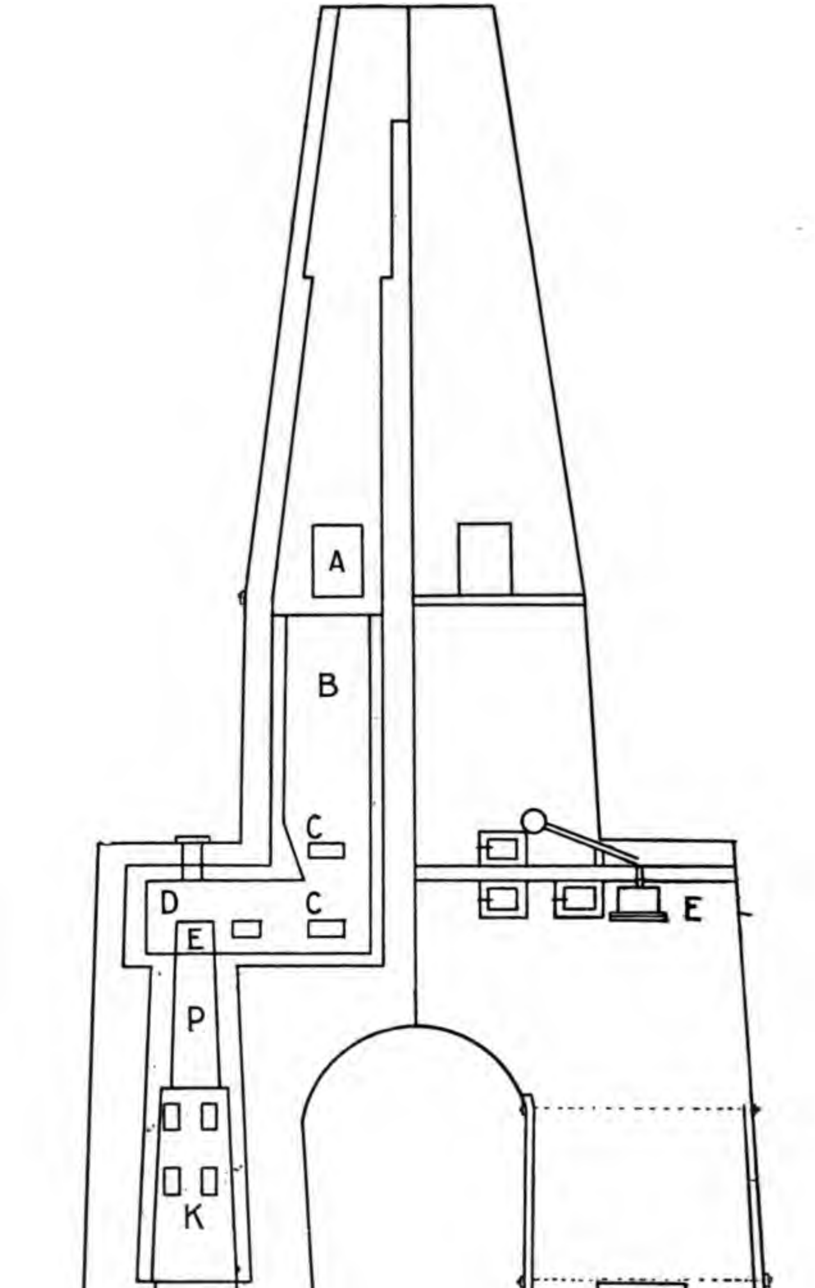


Dome type of kiln, after Butler



Dietzsch kiln, after Butler

the older processes. Crude or fuel oil is used at all the American factories where this type of furnace is employed. Producer gas could no doubt be employed. It is claimed by Johnson that this type of kiln is used only at those works where the mixed materials will not adhere with sufficient firmness to permit molding into bricks.

Dome kiln (pl. 14). This is one of the oldest types used, and is the simplest. The kiln is charged by placing kindling at the bottom, and then alternate layers of coal and slurry cake are put on, till the kiln is full enough. The fire is then started, and burns slowly upward through the mass, the temperature gradually increasing. The doors at the bottom are then opened and the clinkers discharged through them. The kiln is recharged for another burning. The recharging occurs about once in a week or 10 days. The proportion of underburned and overburned clinker depends on the relative amount of fuel and slurry used. As fuel burns out, fresh material can be added at the top, or the whole mass can be allowed to burn out and be removed without recharging the kiln. There is much waste heat, which is sometimes utilized for drying the slurry, but the utilization of this should in no way interfere with the working of the kiln.

When the kiln is intermittent in its action, there is of course a great loss in heat. There is probably also much cost for repairs, as the heating and cooling tend to crack the walls. This kiln is rather expensive in fuel and produces an output averaging only 3 to 6 tons of cement a day in a month's run. A good deal of sorting and picking of the clinker is required to exclude the underburnt and vitrified material. Till 1889 these were the only kilns in this country.

Dietzsch kiln (pl. 15). This is continuous in its action, and has been in use in some works for a number of years being patented in 1884. The fuel used in it is generally coal slack, and the cost of calcination, comparing this with the "bottle" kiln is small, but the slurry has to be dried before introduction, and there is no available waste heat for this purpose. The working part of the kiln is divisible into three sections, viz, a heating, a burning, and a cooling chamber.

Butler describes it as follows:[1] (*see* pl. 15)

> Supposing the kiln to be in operation, the cooling chamber H would be filled with calcined clinker, which is being cooled by the cold air passing through it on its way to the burning chamber F. The cooling chamber thus serves the double purpose of cooling the clinker and giving its heat to the entering air.
>
> The burning chamber is filled with slurry.
>
> The heating chamber B is filled with slurry, which is introduced at A. At fixed intervals, generally about every half hour, a certain portion of the clinker is drawn out at the bottom, which causes a general downward movement of the mass throughout the kiln, while a fresh portion of the slurry heated by the escaping gases is raked forward into the calcining chamber, the necessary fuel being added through the eyes EE.
>
> It sometimes happens that, owing to the clinker being slightly overburned and vitrifying too much, the mass hangs up, and will not drop properly when a portion is drawn from the bottom; to overcome this difficulty, eyes are placed at convenient levels at the lower end of the calcining chamber, so that, with the aid of iron bars, the mass may be detached and again set in motion.

This kiln is said to be very economical in fuel consumption. It however requires constant attention and charging. The labor is great compared with that compelled by the common intermittent kiln, and it has to be watched carefully, so that much of the success in burning depends on the skill of the burner. Butler claims that it yields a large percentage of unburned slurry.

Newberry[2] claims great economy of fuel for the Schöfer type of kiln, specially its modified form, the Aalborg. Only about two tons of soft coal a day are required for each kiln, with a daily production of 75–80 barrels of cement clinker. This is only about 12% of the weight of the clinker produced, and with coal at $2 a ton corresponds to a cost for fuel of only 5c for each barrel of cement produced.

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[1] Butler, D. B. Portland cement.

[2] 18th an. rep't U. S. geol. sur. pt 5, p. 1176.

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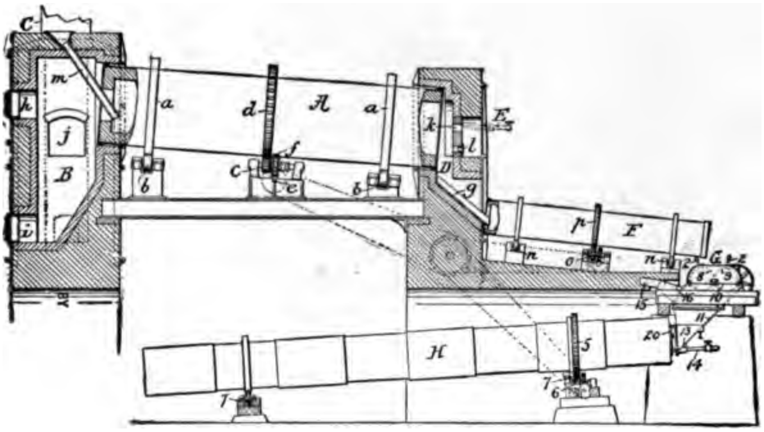
ASTOR, LENOX AND
TILDEN FOUNDATIONS

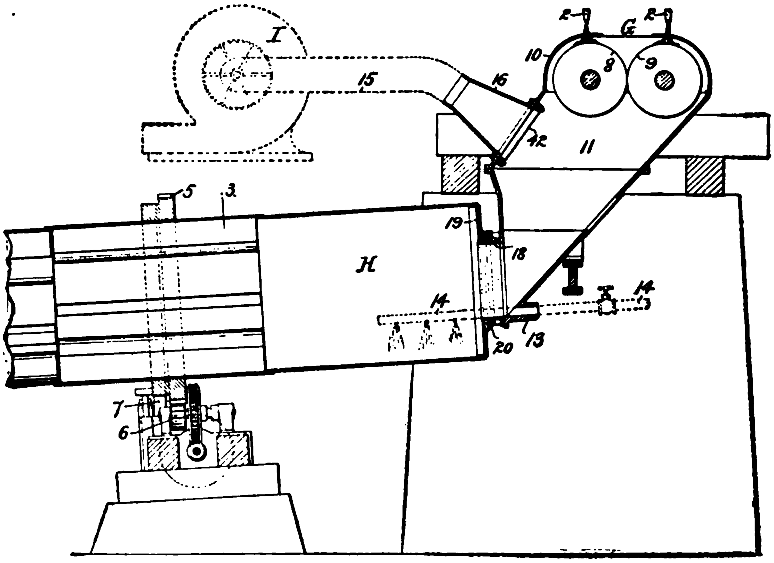
Plate 17 To face p. 711



Section of American rotary cylinder kiln for burning Portland cement (Mineral industry, 6:107)

Plate 18

To face p. 711



Detail of cooling chamber of rotary kiln (Mineral industry, 6:109)

Rotary kiln. This consists of an inclined revolving iron cylinder lined with fire brick (pl. 17). The slurry or dried mixture is charged at the upper end, and oil or gas fuel blown in at the lower, the gases of combustion passing through the chamber and out at the upper end, while the cement mixture slowly passes down through it, the burned clinker being discharged at the lower end.

At the present time the rotary kiln is gaining favor in the United States. It is claimed by Lewis[1] that the cost of oil fuel in this type of kiln is 28 to 40c a barrel, depending on the price of oil, but, using powdered coal, the fuel cost is greatly reduced.

There has also been a great improvement in the mechanical features of the kiln.

In this country the rotary kiln was first experimented with in 1889, when the Atlas cement co. of New York began to experiment at Coplay (Pa.) with revolving continuous kilns, employing crude petroleum for fuel. The oil was blown in by jets at one end and the products of combustion passed into a stack at the upper end of the inclined revolving cylinder. This kiln has been patented in England by Frederick Ransome, who also secured an American patent for it. Since 1889 its success has increased in America, and, though this type of kiln is said to have been unsuccessful in England, in this country there are no less than 40 of them in operation, both on the hard raw material of the Lehigh valley and on the soft, wet marls of Ohio and Michigan, and also limestones of New York. The revolving continuous kiln is perhaps therefore an American device, since its only successful development has been in this country. Originally employed with producer-gas, it was subsequently modified so as to use jets of crude petroleum, while latterly experiments have been made with a view to utilizing pulverized coal as fuel, and several plants are working kilns employing this fuel.

Certain improvements in the way of auxiliary cylinders for regenerating the heat in hot clinker have been perfected, and the Atlas cement co. has also worked out a scheme for sprinkling and cooling the clinker in a third cylinder, so that, when discharged from this, it will be ready for immediate grinding in the mill (pl. 18).

---

[1] **Min. ind. 7: 113.**

Hoffman ring kiln. This is used at a number of works in Germany but thus far has not been introduced into the United States. It is circular in form and consists of a number of chambers which are connected by flues with a central stack, and also with each other. The fuel is charged through the top and the kiln is down-draft in its action. The fire is started in the first chamber, and the heat from that is used to heat up several of the subsequent ones before it passes off to the stack. The material is dried preferably in the shape of bricks.

The advantages are: saving in fuel of 10% to 20%; combustion more perfect than in dome kiln; kiln well under control; burning can be watched. The disadvantages are: not economical unless run continuously; material of chamber lining should be as basic as possible to avoid union with silica of cement.

There are about five different types of kilns in use in the United States at the present time, requiring three different methods of preparation for the raw materials, regardless of differences of preparation which may be required by the character of these materials. The following list quoted from Lewis may serve as partial illustration of this point.

MANUFACTORY	KILN	No.	Approximate output a day Barrels
Coplay cement co.........	Schöfer continuous...	9	55
Coplay cement co..........	Ordinary intermittent	23	30
American cement co., Egypt.	"	56	30
American cement co., Jordan	"	6	30
Atlas cement co............	Revolving continuous	20	150
Alpha cement co...........	"	8	150
Vulcanite co.	"	3	150
Sandusky co.	"	4	120
Bronson co.	"	3	120
Empire co.................	Ordinary intermittent	18	130
Glens Falls co.............	Schöfer continuous ..	8	60
Whitecliffs Ark.	"	8	60
Buckeye cement co.........	Ordinary intermittent	..	30

MANUFACTORY	KILN	Approximate output a day No.	Barrels
Buckeye cement co.	Dietzsch continuous	...	50
Diamond cement co.	[1] continuous	..	...
Yankton S. D.	Johnson intermittent	6	...
Bonneville cement co.	Revolving continuous	3	150

A new plant near Egypt (Pa.) and another near Sandusky (O.) are both installing revolving continuous kilns, as is also one at Catskill (N. Y.)

Grinding the clinker. American practice uses a combination which has brought this step in the manufacture of Portland[1] cement to a high degree of perfection. The machinery used is in part of American manufacture and partly of foreign origin.

It has been found that the best results are obtained by using a gradual reduction of the clinker instead of attempting to grind it all fine at once, and, with this object in view, it is common to break the material up first into lumps by means of crushers of the Gates or Blake type and then pulverize it in ball or tube mills or mills of the Griffin type. Ball mills are sometimes used for the first grinding but in that case in conjunction with Danish tube mills.

The absence of separators is sometimes commented on, it being claimed that, if the sufficiently fine material were removed after each grinding, the capacity of the machines would be increased. Wind separators are occasionally used abroad, but find very little application in American practice. The following table, taken from the *Mineral industry,* v. 6, gives the fineness of different brands of native and foreign cements.

	Per cent passing sieves No. 50	No. 100	No. 200
Saylors	100	96.4	....
Giant	99	94.9	....
Atlas	99.5	92.7	....
Alpha	99.7	94.8	....

---

[1] Rebuilding.

	Per cent passing sieves No. 50	No. 100	No. 200
Vulcanite	99.6	95.3	....
Sandusky	99.6	92.8	....
Brooks, Shoobridge & Co	98.8	88.3	....
Aslen	99.7	92.4	68.4
Aalborg	100	99.6	72
Condor	99.6	88.5	....

Ball mills. At many factories a ball mill is used, which consists of a revolving cylindric chamber, divided into segments with inclined steps. In this chamber is placed the clinker together with a number of flint balls, and, owing to the rotating action, the clinker is pulverized. The surface on which the balls travel is of hard metal. It is also perforated so that, as soon as the clinker is ground fine enough, it falls through on a metal screen, which retains the coarser grit, the finer particles passing on through gauze. Pl. 19, 20 show a sectional view of a ball mill.

Tube mills (pl. 21). These are also used for the reduction of the clinker, and consist of an iron cylinder about 15 feet long and 4 feet in diameter, half filled with flint balls. The chief object of the tube mill is to complete the grinding of the cement, the preliminary grinding of the clinker taking place in some other machine.

The cylinder rotates at a speed of 25–30 revolutions a minute, and the material, which is charged at one end, gradually works its way out to the other, though the mill is horizontal. The lining of the mill is either of cast iron strips or specially prepared brick. The material fed to it should have been previously crushed to 20 mesh. If used in conjunction with millstones, they take the heaviest part of the wear off the latter. Their capacity depends of course on the fineness to which the material is to be ground. Butler[1] gives the following figures illustrating the capacity of these mills under given conditions.

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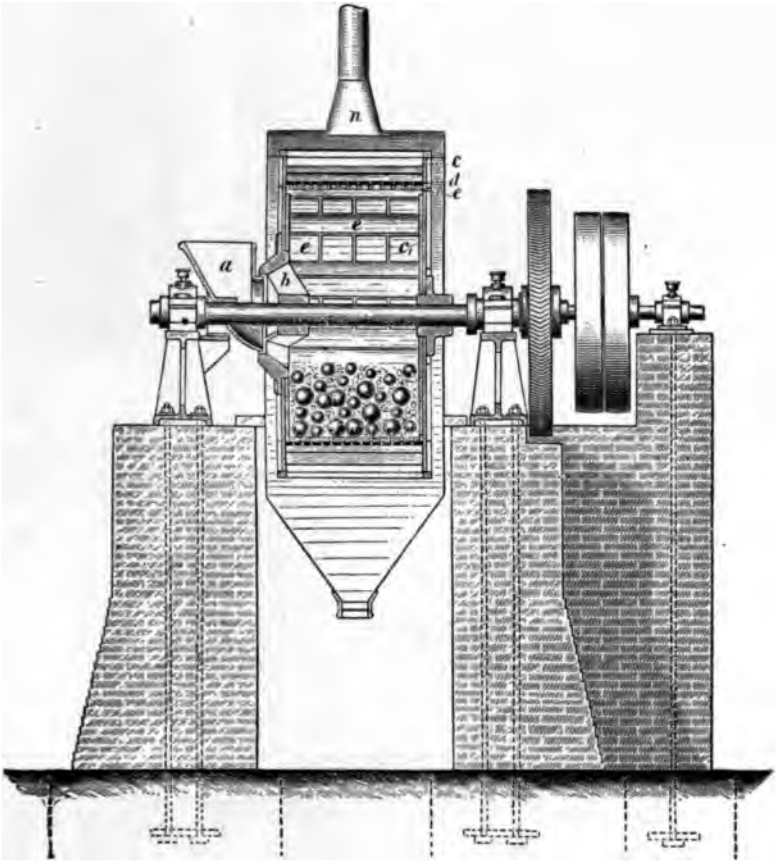
[1] Portland cement, p. 140.

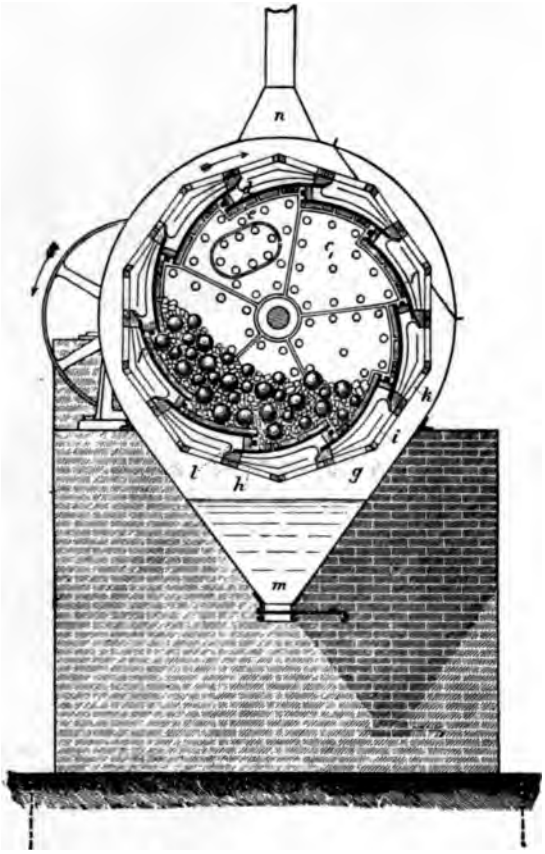
Plate 19 To face p. 714



Section through shaft of ball mill used for grinding cement clinker (F. L. Smidth & Co.) *c* **endplates;** *d* **drumplates;** *e* **steel plates for protecting drumplates.**

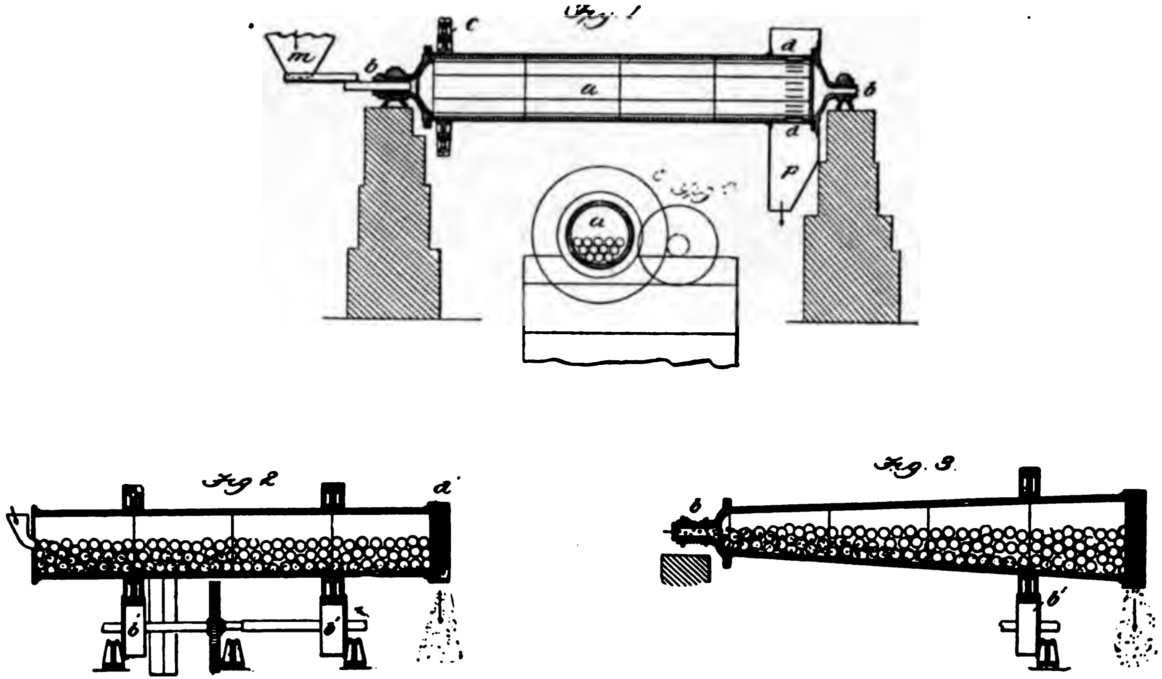
Plate 20

To face p. 714

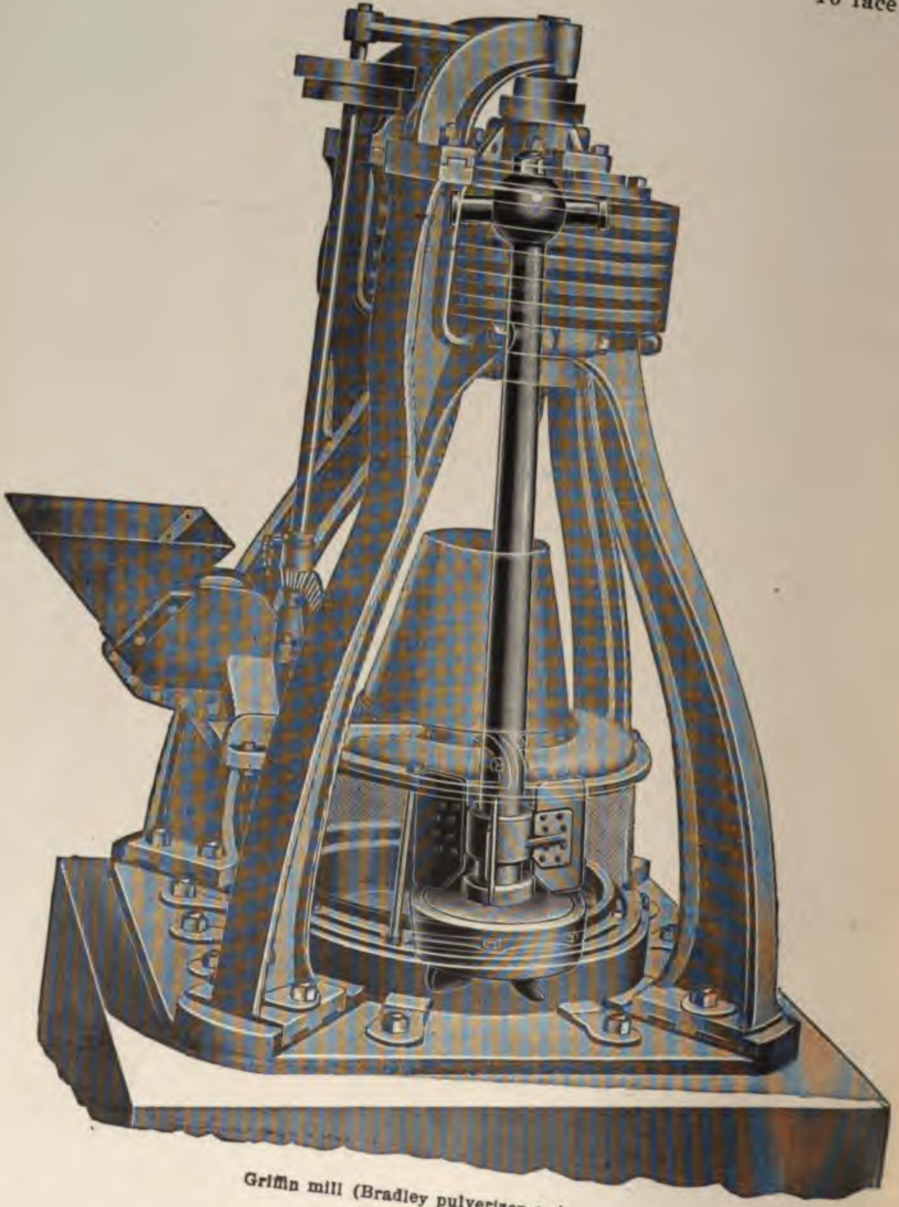


Section through ball mill showing grinding plate and sieve arrangement (F. L. Smidth & Co.) *f* perforations in grinding plates through which crushed material falls on screen plates; *g*, *i* inner sieves; *k* finishing sieves, the screenings from which are caught in hopper *m*.

Plate 21



Sections through Davidsen tube mill (F. L. Smidth & Co.)
a drum; *b* bearing pivots; *c* cogwheels for rotating drum; *d* discharge openings; *m* supply chute; *P* discharge chute



Griffin mill (Bradley pulverizer co.)

Residue to the linear inch of sieve-holes

	180 per cent	100 per cent	76 per cent	50 per cent	OUTPUT
1 Material entering mill........	47	38	34	28	2½ tons an hour
Material leaving................	23	12	6	1	
2 Material entering....	72	67	62	56	4¼ tons an hour
Material leaving...........	37	24	16	6	

At many works the ball mills and tube mills are used in connection with each other.

Griffin mill (pl. 22). The Griffin mill is used at some factories for grinding the finished product. It consists of a steel ring, against the inside surface of which a heavy steel roll revolving on a vertical shaft presses by centrifugal force. The mill is provided with screens, so that, as soon as the material has reached the required fineness, it can pass through, the coarser particles however dropping back into the mill. This type is much used in German and other continental works.

The Griffin mill is used chiefly for grinding those particles which have been rejected by the sieves, and often in conjunction with millstones. In many factories however it performs the entire work of reduction. The crushing roll is attached to a shaft suspended vertically from a ball joint. To the bottom of the roll there is attached a series of plows or stirrers, so that, when the pan below contains sufficient material to come in contact with the plows, it is thrown up between the crushing roll and the die.

Two sizes of this machine are made, the diameter of the ring or die of the smaller being 30 inches and of the larger 36 inches, the diameters of the respective rolls being 18 and 22 inches. The pulley speed for each machine is 200 and 150 revolutions a minute.

Butler states that, at one mill where two of these machines are in use, of 30 and 36 inches respectively, the larger mill is worked on tailing from the separators only, the hourly output being 38–40 cwt when ground to about 2% on 50. The smaller sized mill is worked on tailings from the separators and clinker from the crusher mixed, a rough grating being placed in the clinker hopper to prevent any pieces larger than a walnut from going forward into the mill, as such pieces would choke the worm feed. The smaller mill under these conditions is said to yield 26–30 cwt an hour.

Mills compared. H. Faija makes the following comparisons.

The power consumed by the several principles, reduced to the proportions of 1 ton of cement an hour, may be approximately stated as follows: for millstones 30–32 horse power per ton an hour; ball principle 16–18; edge runner principle 12–14. In each case the cement is ground to a fineness of a 5% residue on a 50 x 50 sieve, and it will thus be seen that the power required is proportionate to the amount of flour produced.

Butler declares, from microscopic analysis of different cements, that the statement that millstones produce an angular grain, and edge runners a rounded one, is incorrect.

Testing

There are as yet no universally accepted standard methods of testing, but the characters which may be, and often are determined are: compressive strength; tensile strength; rate of setting; boiling test; abrasion; permanency of volume; degree of fineness; adhesion; specific gravity.

Mixing the mortar

In 1885 the American society of civil engineers suggested testing briquets of neat cement, and, in addition, briquets of cement and sand: those of natural cement with one part sand, and those of Portland cement with three parts sand by weight. Some authorities advocate the abandonment of the neat cement test, since in use the material is always mixed with sand. The ratio of sand to cement is commonly 3 to 1 in case of Portland and two to one in case of natural rock cement.

Johnson states:

> For special purposes 4 to 5 parts of sand may also be employed, specially with finely ground cements, such as give a residue of less than 10% and a sieve with 14,400 meshes per square inch. Since in the sand mixtures a standard sand must be employed, it has become necessary to use clean sharp sand which has passed a no. 20 sieve and stopped on no. 30.

In order farther to insure the identity of the sand, the American society of civil engineers has recommended that crushed quartz be used, such as is used in the manufacture of sandpaper. Johnson does not favor this practice; for the material has fully 50% of voids, while the ordinary sands with roughly rounded grains have but 33% of voids. Any good sharp sand therefore of the size, 20–30, should give very nearly uniform results, which will average much higher than those obtained with crushed quartz, unless the quartz briquets be thoroughly compacted by hard hammering.

The amount of water added will vary somewhat with the kind of cement, but it should be very little, in fact just enough to produce a mixture resembling damp sand. Jameson gives the approximate amounts (p. 55) as 20% to 25% for neat cement, 15% for one part sand, and 10% to 12% for three parts sand. It is always well to note the amount of water used. The temperature of the water and also of the laboratory should be between 60° and 70° F.

The mixing should always be done on a non-absorbent surface, and the sand and cement should be mixed dry, and then the water added.

Compressive strength

The test for compressive strength is seldom carried out, the reason being that the results are apt to be uncertain even though care be taken in the preparation of the specimens. They must be all exactly of the same size, and have the sides exactly parallel and the ends exactly perpendicular to them. This is only obtainable when large cubes are used, and these require great machines to crush them.

M. Gary states[1] that in order to obtain agreement between different compression tests, the specimens should be made by machinery, and gives the following directions.

Take 400 grams (14 ounces) of cement and 1200 grams (42.2 ounces) of dry standard sand, mix thoroughly in a dish, add 160 grams (3.6 ounces) of water, and work the resulting mortar thoroughly for five minutes (quicksetting cements are to be worked but one minute). Put 860 grams (30.3 ounces) of this mortar into the cubic mold properly provided with filling cases and fastened to the bed plate. The iron core is placed into the form, and 150 blows are delivered on it by means of the hammer apparatus, with the hammer of 2 kilograms (4½ pounds) weight. The filling cases and core having been removed, the specimen is struck off flush, smoothed and drawn off the bed plate together with the mold.

For neat cement specimens, mix about 1000 grams (2.2 pounds) cement with the requisite amount of water. The molds should be oiled a little, and can be removed only after the cement has sufficiently hardened, which is usually from 20 to 24 hours after making.

While the elasticity of Portland cement decreases after some years, and the tensile strength ceases to grow after a similar period, its compressive resistance increases.

The machines used for determining the compressive strength are similar to those employed for the crushing of building stones and bricks. The compression test is seldom carried out in the United States.

Tensile strength

To carry out this test the cement is mixed with water to the consistency of a stiff paste and formed into briquets, this being done by means of brass molds.

When the cement alone is used it is spoken of as "neat" cement. When mixed with sand the term "cement mortar" is

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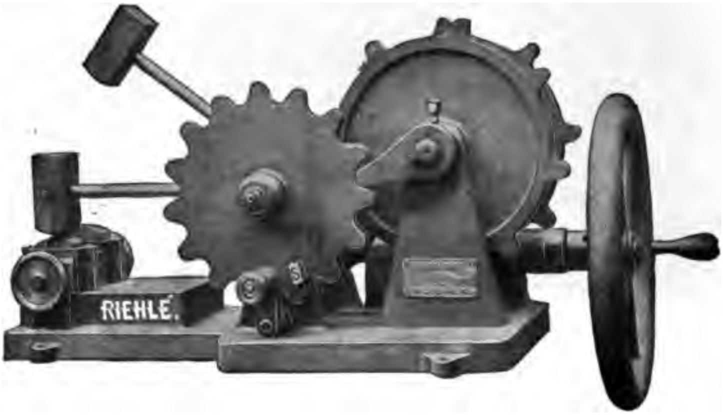
[1] Trans. Am. soc. civ. eng. 30: 25.



Böhme hammer, used for making cement briquets (Riehle Bros.)

applied to it. The briquets are allowed to "set" either in air or water and are then pulled apart after a time, the number of pounds a square inch required to do this being recorded. This is the usual test made on cement, and, while it is not subjected to a tensile strain in actual work, still it gives a good idea of the strength of the cement, and is easily carried out. The briquets should be made of cement taken freshly from the barrel.

Form of briquets. Several different forms of briquets have been devised, but all have been so designed as to cause the briquet to break at its minimum cross-section. The American society of civil engineers recommended a standard size of briquet, which is one inch thick and the same in width and weakest in the center. This is smaller than that which is made in England or on the continent, but it gives satisfactory results, and the smaller size makes it less likely to have air bubbles.

Briquets may be made either by hand or by machine. When made by hand, the mortar is mixed with a trowel and pressed into the mold with it also. It is always desirable for the same person to make all of one series of briquets. It is claimed that, when the material is pressed into the mold with the trowel, the pressure exerted on the briquet is not evenly distributed over the surface. The briquet molds are usually constructed of brass, and are made in two pieces.

Molding briquets. There will always be some variation in the tensile strength of briquets. Jameson claims that, with the use of his briquet-molding machine, the variation was reduced to about 4%[1]; and the Böhme hammer (pl. 23) is said to accomplish the same object.

Heath in his *Manual of lime and cement,* p. 83, gives the following method for insuring uniformity in the briquets:

"The mixed cement is to be lightly placed in the molds, and is then to be pressed for five minutes under a load of 10 pounds placed on top of the soft cement projecting above the mold." The loading block is shaped to the mold with $\frac{1}{64}$ of an inch clearance and is to be placed on the cement symmetrically; after loading, the surplus cement is to be cut off with a trowel or a knife, and the briquet smoothed level with the top of the mold. "With the exercise of the greatest care, the handmade briquets do not compare with those made with the machine."

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[1] **Jameson. Portland cement, p. 54.**

Another advantage of machines is the rapidity with which the briquets can be made, and an additional advantage of this is that a lot of material can be mixed up at once.

In making briquets by hand enough material is usually mixed to make four or five briquets at once, and this is necessary if the material is at all quick setting.

All tensile test briquets should be kept in a moist atmosphere for 24 hours, and then kept the remainder of the period in water. It is important that the water used in mixing and also the bath in which the briquets are immersed should be kept at a constant temperature, so that uniform results may be obtained. Thus it has been found that in Portland cement the time of setting is shortened by increasing the temperature of the mixing water, while the strength attained in a given time may be greatly increased by raising the temperature of the bath from 40° to 80°[1]. In case of normal mortar, 1C: 3S, this increase at two months was from 100 to 230 pounds per square inch.

Briquet machines. The object of these is to bring about uniformity of pressure in the molding of the briquets. A number of such machines have been devised but comparatively few of them are in use. The Böhme hammer is a machine much used in Germany for this purpose (pl. 23). According to M. Gary[2] it consists of a tilt hammer with automatic action. The hammer is driven by a cam wheel of 10 cams actuated by simple gearing, and the wrought iron handle of the hammer is let into the crosshead which carries the axle of the hammer, and keyed to this crosshead and to the cap, so that it may be readily replaced if worn. The steel hammer, weighing 4½ pounds, is similarly fastened to the cap. As soon as the intended number of blows has been delivered, the mechanism is automatically checked, the machine having been so adjusted before the beginning of the work.

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[1] Johnson. Materials of construction, p. 408.

[2] Trans. Am. soc. civ. eng. 30: 24.

The number of blows required in the standard German tests is 150. The forms to receive the mortar consist of a lower and upper case held together by springs. The lower case for compression specimens consists of two angle irons held on a plane plate by a grinding strip and a screw acting on the latter. Upward motion is prevented by two wedge-shaped surfaces. The lower case and half the upper ones are filled with the mortar to be tested, and a plate laid on its surface. On this plate the blows are delivered. It is of vital importance that the apparatus should rest on a firm non-elastic base.

The Jameson machine[1] is described by the author as follows:

> The main portion of the machine consists of a cylinder, which is flanged at the lower end, this flange corresponding in size and shape to the upper part of the base. The cylinder is bolted to the base by four bolts, each bolt provided with a filler that holds the lower face of the filler 1 inch above the base plate. Both of these faces are accurately planed. It is between the two plane faces that the molding plate swings, the fillers on the bolts acting as stops. The bore in the cylinder is the shape and size of the briquet. In the bore there works a solid plunger, and the length is sufficient to cover the feed hole when at its lowest points. This plunger is operated by a lever. At either side of the plate are two extractors which correspond in outline and size to the opening in the plate, and which are raised by means of levers thus forcing the molded briquet from the plate.

A high capacity is claimed for this machine, it being stated that three students have made 3000 briquets in 10 hours.

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[1] **Jameson. Portland cement, p. 50.**

Cement-testing machines. A number of different machines have been devised. The two generally used in this country are Fairbanks's and Riehle's.

In the Riehle machine (pl. 24) the strain is applied to the specimen by means of a screw attached to the lower clip. The upper clip is attached to a graduated steel bar on which there slides a weight. This bar is kept balanced during the test by moving the weight along it with the aid of the upper wheel. Both wheels must be operated at the same time, and the end of the upper beam or indicator kept as nearly as possible in the middle of the opening in which it moves. The amount of strain on the specimen is shown by the position of the sliding weight.

The Fairbanks machine is of more compact form, and its construction is best understood by reference to the figure. After putting the briquet into the clips the levers are balanced, and the hopper filled with shot. This is allowed to run out into the bucket till the briquet breaks, when the stream of shot is stopped automatically (pl. 25).

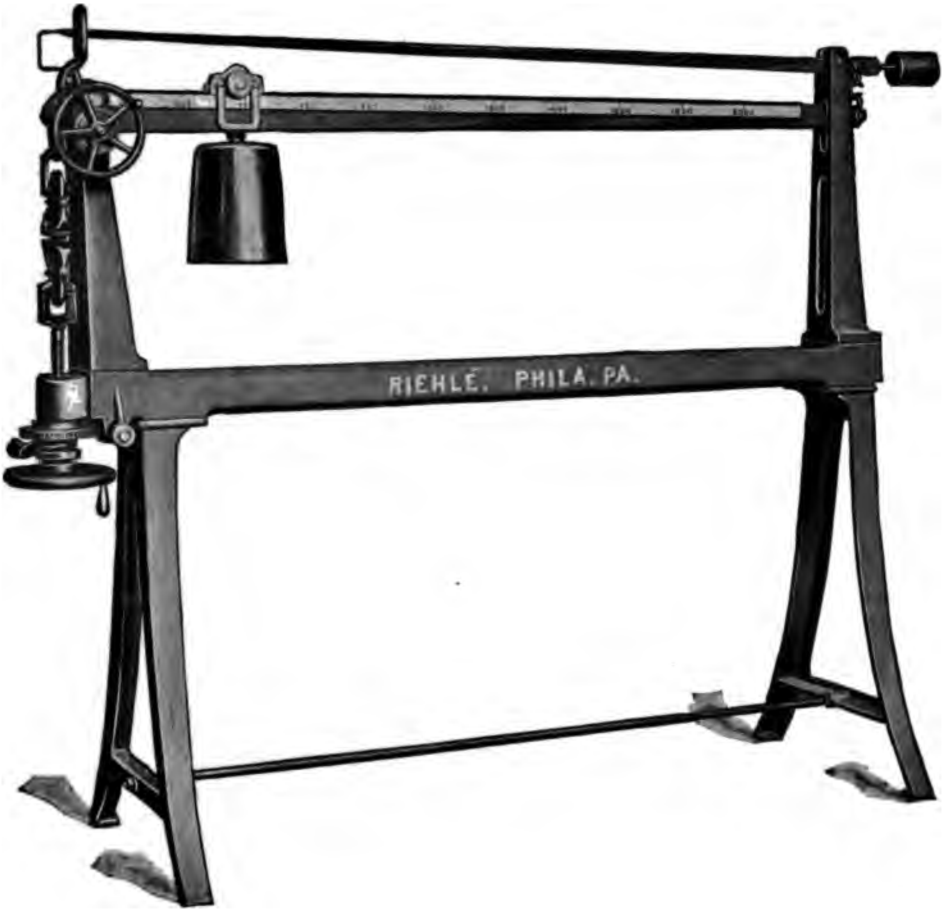
Clips. Several forms of clips are made. The early ones had rather sharp edges which came in direct contact with the briquet; but this has been found objectionable, partly from the fact that the briquets were not always of just the right form to insure a perfect bearing. The result of this was that a false strain was often brought on the briquet, causing it to break at a lower point than it really should, and also at some other point than its minimum section. This trouble has been overcome in a measure by introducing cushions between the metal and the briquet, or even supplying the edges of the briquet with rubber rolls.

Johnson gives the essential features of the clips as follows.

1 They must grasp the briquet by a hard cushion bearing on four symmetric flat surfaces.

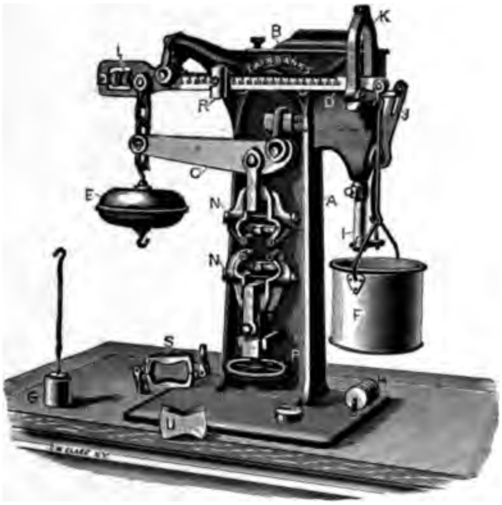
2 They must be freely suspended from a pivot bearing, so as to turn without friction while under stress.

Plate 24 **To face p. 722**



Riehle Bros. machine for testing cement briquets

Plate 25 To face p. 722



Fairbanks machine for testing the tensile strength of cement briquets
N clips for holding briquets; P screw for applying strain to balance lever C; F bucket to hold shot, fed in through I, from the hopper K; J automatic cut off

3 They must be so rigid that they will not spread appreciably when subjected to their maximum load.

Placing briquet in machine. This should be carefully done, seeing that not only is the briquet in straight, but also that it has a full bearing surface. The pressure should be applied slowly, not faster than 500 pounds a minute. A note should be made of the number of pounds required to break the briquet and also of the character of the break. When the fracture is uneven, or does not occur at the minimum section, a note is always made of the fact, and the cause of this should be ascertained if possible.

Sand used. Two kinds of sand are used in cement tests, depending on the object for which the tests are being made. In the one case, when the cement is to be used in a particular piece of work, then it should be mixed with the sand that it will be mixed with in the actual work of construction.

If the cement is being tested simply for comparative purposes, or there is uncertainty as to the quality of the sand, then standard sand should be used. The standard is clean crushed quartz of such size that it will go through a no. 20 sieve, but be retained on a no. 30 sieve.

After molding and removal from the molds the briquets are set on non-absorbent slabs for 24 hours under a damp cloth, after which they are removed, half of them being put under water. The style of the tanks or pans used varies with the arrangement of the laboratory and the fancy of the person making such tests. The briquets when placed under water are always set on edge.

Temperature of briquets. In cements there may be a slight increase in temperature following the molding, which is due to the presence of free lime. In good Portland cements this rise in temperature is very slight, but is often sufficient to be felt by placing the hand on the briquet. In light burned natural cements there is often an appreciable rise in the temperature.

Setting of cement

By the setting of cement is meant the change that takes place from a soft mass to a hard brittle solid. This change, while varying in different cements, is on the whole a very rapid one at first, and then proceeds more slowly. It is always accompanied by the evolution of heat. The change which takes place is that in the burning of the cement an anhydrous silicate of aluminum and lime is formed which is soluble in water. On solution taking place the material at once changes to a hydrate which is insoluble and consequently crystallizes out, this crystallizing action causing the hardening.

A number of different ideas are held on this point, and the problem is a very complex one, which has as yet been only partially solved. Fremy considers that the formation of an aluminate of lime is responsible for the hardening property, and he also considers that the silica and alumina of the clay are separated by calcining and take on allotropic forms ready to unite into new compounds with the quicklime when the water is added. The work of S. B. Newberry in this line is of the highest importance, and has already been referred to (p. 697–99).

The set of the cement is determined by what is known as the needle test. Gen. Gilmore was one of the first to use this test in this country. It consists in determination of the penetration of a needle of wire of known cross-section and of given weight. The needle used by Gilmore as described by him was slightly conical, tapering toward the point, and truncated at right angles to the axis so as to give a diameter at the lower end of $\frac{1}{12}$ of an inch. It protrudes from a socket at the lower end of a spindle or vertical rod, to which it is firmly secured by means of a thumbscrew. To the upper extremity of the spindle is attached a diagonal scale of steel, accurately graduated to tenths, hundredths, and thousandths, of an inch, and provided with a horizontal index firmly fixed to the framework of the instrument. The absolute penetration of the needle is obtained by taking the difference of the readings on the index before and after the impact. The falling body is a hollow metal cylinder, weighing 1 pound, of which the exterior diameter is about equal to the length. This cylinder in its descent passes freely over the spindle and strikes on the shoulder attached just above the screw.

Another device used by Gen. Gilmore was a $\frac{1}{12}$ inch wire with a flat end, and loaded with $\frac{1}{4}$ of a pound, and a $\frac{1}{24}$ inch wire also loaded with 1 pound. These were used on cakes of neat cement, 2 or 3 inches in diameter, $\frac{1}{2}$ inch thick at the center, and $\frac{1}{4}$ at the edges. One cake was left in the air and one in the water. The time at which the loaded wire ceased to penetrate the pat was noted.

In England those Portland cements are called quick setting which will bear the $\frac{1}{12}$ inch needle loaded with 4 ounces in 10 minutes after mixing with water, and to be slow setting if they require 30 minutes or more, up to 5 hours. If they will not bear the weight of the needle after this period, the cement is rejected.

Still another test is that with Vicat's needle. The needle has a cross-section of 1 millimeter and bears a weight of 10$\frac{1}{2}$ ounces. The depth to which the needle penetrates the cement is read off on a scale.

A quick setting cement may begin within a few minutes after wetting, while a slow setting one may not begin till 24 hours after it has been wet, though, when once begun, the setting usually goes on rapidly.

Setting is always accompanied by a slight rise in temperature, which continues while the setting is going on. The rise in temperature is less in slow setting cements. As the setting of cement is also influenced by the temperature of the air and water, it is recommended by Gary that, in order to obtain comparable results, the tests should be made at a mean temperature of 15° to 18° C.[1]

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[1] Trans. Am. soc. civ. eng. 80 : 11.

Portland cement becomes slow setting through long storage, though at first it may gain in its setting speed if kept in a dry place free from drafts.

Jameson also states that some cement, when taken from the mill and gaged with water, is found to be moderately slow setting, but after 24 to 30 hours will set almost before it can be mixed. Store it in a cool, dry place and in a few days it will become slow setting.

The speed of setting usually decreases with the age of the cement, provided it has been stored in a dry place. Some consider that slow setting is due to free lime, but other factors also enter into the problem, such as the underburning or overburning of the cement, the underburned setting quicker. A vitrified cement will never set.

Boiling test

This is the one that has been recommended as the best for determining the soundness of a cement. At the fifth international convention for unifying methods for testing construction materials, held in Zurich in September 1895, the rules for conducting this test were laid down as follows.

1 The rapidity test of hydraulic cements for constancy of volume consists in the application of warm baths at temperatures of from 50° to 100° C.

2 Manner of making test pieces. Enough water is used to bring the neat cement after proper working into a plastic state. Two balls from 1.5–2 inches diameter are formed by hand and kept in moist air resting on some non-absorbent material. (Sand mixtures are not subjected to this test, neither are briquets that are to be tested for tensile strength.) The employment of tension briquets and cylindric disks from 2 to 4 inches in diameter, from ¾ to 1¼ inches thick, is likewise permitted.

3 Duration of previous hardening. Till set has taken place, test pieces must be kept in moist air. Portland, slag, pozzuolana, and Roman cement will be kept uniformly thus for 24 hours,

very slow setting cements for 48 hours. Hydraulic limes and all cements that have not set after 48 hours will be allowed 72 hours for previous hardening.

4 Treatment in the water bath. The previously hardened test samples are placed in a water bath at the ordinary temperature, which is then gradually — in not less than 30 minutes — heated to the prescribed temperature and kept there. After three hours at this temperature the test is interrupted, the test pieces are taken out of the bath, and, after having cooled sufficiently, examined as to their condition. They must not be chilled suddenly by means of cold water.

For each warm bath test the water must be renewed. The temperature of the bath will be: for Roman cements and hydraulic limes, 50° C. Portland, slag and pozzuolana cements, 100° C.

5 In order to be considered of absolutely constant volume, the sample must, during the test, remain perfectly sound and entirely free from cracks and warping. If the ball cracks slightly in this test or disintegrates somewhat, it should be considered at least as doubtful, though it might not fail in actual practice.

This test is not good for natural cements, as they will not stand it in most cases.

Abrasion test

This is sometimes applied to neat cement and also to mixtures of cement and sand when they are to be used for flooring. It depends on hardness of cement itself and also on its cementing qualities.

Jameson states that the grinding machines are of two kinds. A Berlin form is a cast iron disk that rotates 22 times a minute. The cube after seven days' immersion and drying is held on the disk with a clamp weighted to 56 pounds. 308 grains of Napus quartz is put on the plate at the start and at the end of the 15th revolution. After 30 revolutions the cube is weighed and the loss noted. Jameson uses a cube 3 inches on edge, and a coarse emery wheel 4 inches in width and 15 inches diameter. The wheel is set vertically and given 100 revolutions a minute. The cube was loaded with a weight of 10 pounds at the end of a lever 3 feet long, and subjected to 200 revolutions.

The following figures given by Gary[1] show the loss by abrasion which some cements suffer.

Loss of weight by abrasion

No.	Length of tests	HARDNESS IN AIR					HARDNESS UNDER WATER				
		neat cement	1 cement 1 sand	1 cement 2 sand	1 cement 3 sand	1 cement 4 sand	neat cement	1 cement 1 sand	1 cement 2 sand	1 cement 3 sand	1 cement 4 sand
1...	7 days..	5.5	4.2	3.5	6.1	8.9	5	3.7	3.8	7.9	10.4
	28 ..	7.9	4.5	1.9	9.7	13.8	2.9	1.8	2.7	4.1	6.8
2...	7 ..	4.6	2.5	3.4	8.3	9.5	4.6	1.7	3	6.5	8.8
	28 ..	3.9	2	3.5	6	7.3	3.6	1.8	2.3	5	5.6
3...	7 ..	5.4	2.9	6.1	18.3	62.8	2.4	2.1	2.1	4.7	15.9
	28 ..	2.4	1.6	1.9	2.3	22.9	2.2	1.3	1.4	1.8	2.2
4...	7 ..	10.4	3.9	3.9	7.3	17.3	4	2.6	2.5	3.6	4.6
	28 ..	9	4	3.4	5.2	14.9	3.6	2.8	2.1	2.1	1.8
5...	7 ..	10.6	7.6	10.2	19.2	28.7	7	5.9	7.1	15.7	17.4
	28 ..	5.3	1.6	1.6	9	11.6	5.8	.9	1.1	2.3	13.4
6...	7 ..	6.2	2.3	4.2	6.5	17.1	3.5	1.3	2.2	5	10.9
	28 ..	5.3	2.2	3.3	4.4	8.9	3.9	1.3	2.2	2.7	3.9

No. 1 a Holstein brand of cement; 2, 3, 6 Silesian cement; 4, 5 pozzuolana cement.

All of these cements are said to fulfil the Prussian regulations. They have a tensile strength after 28 days, when mixed 1–3, of over 230 pounds per square inch, and a compressive strength of more than 2300 pounds per square inch. A sieve of 900 meshes rejects less than 10%. They are of constant volume.

The specimens were tested by pressing them with a load of 56 pounds against a cast iron disk, rotating at the rate of about 22 revolutions a minute. 20 grams of Napus quartz, no. 3, were put on plate at start, and a similar quantity at the end of every 15th turn.

The body is weighed when starting and again at the end of the 30th revolution.

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[1] Trans. Am. soc. civ. eng. 30: 40.

Adhesion

This test is usually applied by taking two pieces of glass 4 x 8 inches and 1 or 1½ inches thick. Mix the mortar and place it between them, with the slabs at right angles, and press the mortar out into a layer ¼ inch thick. The sample is allowed to stand 24 hours under a damp cloth, and then immersed in water. They are pulled apart at end of 7 or 28 days. Better results are often obtained by the use of brick and stone instead of glass.

Permanency of volume

Good cements should not expand or shrink appreciably in setting. If there has been any appreciable flaw in the manufacture of the cement, it will tend to expand or shrink, and disintegrate. This expansion is known as "blowing." One of the best methods of testing the constancy of volume of a cement is to mix it with a small quantity of water, and press it firmly into a straight glass lamp chimney. If any expansion takes place, it will crack the chimney. By the same means shrinkage can also be determined, this being done by putting some colored liquid in the chimney above the cement. If the latter shrinks, it will allow the liquid to run down the interior of the tube.

The expansion may take place immediately, or not show till several days after the cement has been mixed, depending on the rapidity of setting of the cement.

Another convenient means of testing for constancy of volume is to mix the cement with water, and make up a few ounces of it into a pat 3 inches in diameter, ¼ inch thick at the edge and ½ inch at the middle. Place this for 24 hours under a damp cloth and then in water. If it shows no cracks at the edges after three days, it will not be likely to blow.

Henry Faija, in the *I. civil engineers,* states that he uses the following method to hasten the test. He takes a vessel in which water can be maintained at a constant temperature of 110° or 115° F, and having a cover, under which and above the water level is a rack on which the cement can be placed. The pat is made and then put on the rack for 6 to 8 hours, after which it is put in warm water from 16 to 18 hours. If at the end of that time it is firm and adheres to the glass, it can be considered safe. If it does disintegrate, it may simply indicate that the cement is too fresh. Cement is said to blow very often if tested 24 hours after making.

In making the pats it is necessary, specially in the case of slow setting cements, to protect them from the sunlight and drafts. For this reason they are covered with a moist cloth.

Gary claims[1] that, according to German experience, all tests to determine blowing with the exception of the German cake method are misleading, and that a swelling of cements (Portland) is really a rarity.

Cements of changeable volume, he maintains, differ in other properties, specially their tensile strength, from Portland cement, so that they are easily recognized. Some cements, however, such as highly magnesium ones, will, when burnt to a clinkered condition like Portland, refuse to swell when first mixed, and sometimes do not show an increase in volume when kept under water till nearly a year later, but they then show the property to a marked degree.

The apparatus used by the Germans for determining change in volume is known as Bauschinger's caliper apparatus, and can be made to show the change in volume that takes place in a specimen over an extended period of time (pl. 26).

It enables one to determine by direct measurement the changes in length of small parallelopipeds of about 100 mm (4 inches) long and 5 square cm (.78 square inch) area with an accuracy of $\frac{1}{200}$ mm ($\frac{1}{5000}$ of an inch). The apparatus consists principally of a stirrup-shaped caliper, having a fine micrometer screw on its right arm, the left being the support of a sensitive lever. The shorter arm of the lever terminates in a blunt caliper point, and is pressed against the measuring screw by a spring attached

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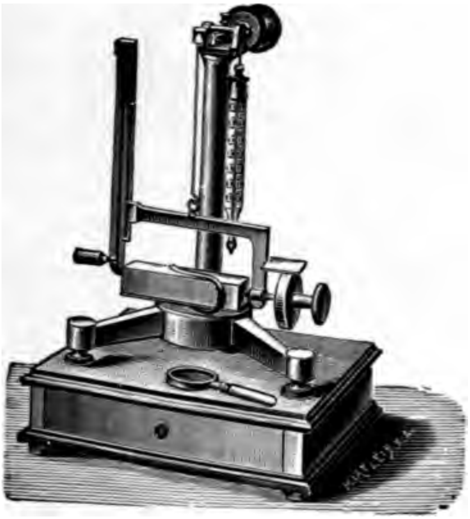
[1] Trans. Am. soc. civ. eng. 30: 15.

Plate 26 **To face p. 730**



Apparatus for determining permanency of volume of Portland cement

to the long arm. The calipers are readily moved in any direction, and the micrometer is read in the usual manner. One revolution of the screw equals .5 mm ($\frac{1}{50}$ of an inch), and readings on the head are made at $\frac{1}{200}$ mm ($\frac{1}{5000}$ of an inch). The specimen is placed on a small platform, between the lever and the screw. The points of the calipers are set on center marks drilled into small glass plates let into the specimens.

The width between the caliper points is made equal to 95 mm (3¾ inches) in each of these instruments, thus very much simplifying the computation for length. For instance, if the screw reads 9.56 revolutions, the absolute length of the specimens is $9.56 \div 2 + 95 \text{ mm} = 99.78$ mm. The specimens are made in small metal frames, just as the standard specimens for tension. It is necessary, however, to turn the molds over repeatedly, and treat both the upper and under surfaces alike. If this is not done, and the upper surface becomes rather thick and smooth, which a repeated striking off with the trowel will accomplish, it may easily happen that the lower layers remain loose and porous, causing a distortion of the specimen, which may lead to considerable errors. The positions for the center-mark plates are provided for in the forms, and these plates may, therefore, be cemented into place as soon as the specimens are removed from the molds. To measure a specimen requires but a few minutes, the apparatus being very easy to manipulate.

In the following table, F and G are two cements which were tested for tensile strength in a 1–3 mortar, and showed but small strength. It will be noted that these two inferior brands showed an extraordinary degree of shrinkage, making them unfit for decorative purposes and laying of face stones. This extraordinary shrinkage explains the cracks shown on so many ornamental surfaces, artificial stones and plates, which always have either a neat cement or a mixture low in sand at their surface. The preference for a really good brand of cement for this purpose is thus explained. The table furthermore shows that the commonly adopted theory regarding a uniform relation between expansion when hardening under water and shrinkage when hardening in air is erroneous.

PORTLAND CEMENT BRAND	HARDENED IN AIR						HARDENED IN WATER					
	Neat cement			Normal mixture 1 to 3			Neat cement			Normal mixture 1 to 3		
	Time of hardening, in days											
	7	28	90	7	23	90	7	28	90	7	28	90
A Ground to ordinary fineness	—.555	—.121	—.134	—.019	—.034	—.086	+.021	+.037	+.048	+.006	+.012	+.033
A Not so finely ground	—.056	—.106	—.16	—.01	—.043	—.06	+.027	+.027	+.008	+.012	+.017	+.02
B	—.101	—.188	—.26	—.025	—.074	—.123	+.003	+.013	+.01	+.005	+.033	+.035
C	—.075	—.118	—.075	—.015	—.02	—.068	+.005	+.02	+.01	+.03	+.005	+.03
D	—.035	—.125	—.195	—.015	—.073	—.09	+.005	+.012	+.019	+.005	+.01	+.005
E	—.045	—.12	—.175	—.028	—.075	—.11	+.027	+.048	+.035	+.007	+.035	+.043
F	—.117	—.252	—.321	—.032	—.072	—.12	+.035	+.035	+.053	+.015	+.02	+.019
G	—.125	—.234	......	—.045	—.058	......	+.025	+.035	......	+.013	+.02	......

Fineness

As the quality of a cement is improved by grinding, it is common to test the degree of fineness. Fineness of grinding, while it improves the quality of the material, also increases the cost of manufacture, up to a point where the increase in cost is more rapid than the increase in quality; but grinding is seldom carried to this point.

The test is to pass it through a 100 mesh linear sieve, the residue remaining on the sieve and also the amount that passes through being noted.

Jameson states that a cement which will pass through a sieve of 625 meshes per square inch and only leave 4–5% residue on a 2500 mesh per square inch sieve is fine enough.

The degree of fineness is of great importance, for the setting is due to the chemical action that takes place between the finest particles of the cement. Johnson states[1] that "The proportion of the cement which passes a sieve of less than about 100 meshes to the linear inch does not give any intelligent idea of the significant fineness of the grinding. In fact, the standard sieve for determining the fineness now generally used on the continent of

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[1] Materials of construction, p. 410.

Europe has 175 meshes per linear inch." 75% of the cement should pass through a sieve of this fineness.

Johnson recommends that a sieve of 120 meshes be used, and that not more than 20% of the cement shall remain on it. Most cements will pass through this.

Sand cement. If Portland cement has a certain amount of sand ground up with it to extreme fineness, it is found that as much sand can be mixed with it to form mortar as could have been added to the undiluted cement. This product is known as *sand cement*, and its manufacture was first begun in this country in 1895 by the Standard silica cement co. of Glens Falls (N. Y.) In Europe it was introduced some time before this, and is manufactured there quite extensively.

According to Newberry, "It is claimed by the manufacturers that the sand cement supplied by them gives only 5% residue on a 180 mesh sieve, and that 6000 barrels of this cement were used in the concrete foundations of St John's cathedral at New York. A description of the industry has been published in the *Engineering news*, Ap. 16, 1896, page 252. This paper gives the following comparative tests of sand cement 1–1, and Portland cement, each with three parts of ordinary sand.

	Pounds to 1 square inch		
	7 days	14 days	28 days
Sand cement 1–1, and 3 parts sand.....	156	188	200
Portland cement and 3 parts sand......	137	170	179

"An extensive series of tests has also been published by Wallin (*Thonindustrie zeitung,* 1896, p. 18) who concludes that the highest economy is obtained by grinding three parts of sand with one of cement." Mr Newberry says:

The good results given by sand cement are easily explainable, for it is wholly a question of filling up the voids in the sand. These voids in ordinary building sand amount to about one third of the total volume; therefore, if more than three volumes of sand be mixed with one of cement, the voids will not be wholly filled. By grinding a part of the sand to great fineness the proportion of voids may be greatly reduced, and a mixture of one cement to six of sand may thus be made as effective as a one to three mixture with ordinary sand. It is evident that very many careful tests will have to be made to determine the precise proportions of cement and sand which will give a sand cement of the best efficiency. There can be little doubt however that the introduction of this new product will tend to increase the consumption of Portland cement, since it will make it possible to use Portland for common purposes at no greater cost than cheap hydraulic cement, and at the same time to obtain greatly superior results.

Specifications for Portland cement

In most countries where the Portland cement industry has assumed considerable importance, the engineering societies of those countries have adopted a series of specifications to govern the quality of Portland cement. The following abstracts of the American, German, and French specifications are quoted from Jameson.[1]

The testing of cement is not so simple a process as it is sometimes thought to be. No small degree of experience is necessary before one can manipulate the materials so as to obtain even approximately accurate results.

The first tests of inexperienced, though intelligent and careful, persons, are usually contradictory and inaccurate, and no amount of experience can eliminate the variations introduced by the personal equations of the most conscientious observers. Many things, apparently of minor importance, exert such a marked influence on the results that it is only by the greatest care in every particular, aided by experience and intelligence, that trustworthy tests can be made.

The test for tensile strength on a sectional area of 1 square inch is recommended, because, all things considered, it seems best for general use. For the small briquet there is less danger of air bubbles, the amount of material to be handled is smaller, and the machine for breaking may be lighter and less costly.

The tensile test, if properly made, is a good, though not a perfect indication of the value of a cement. The time requisite for making this test, whether applied to either the natural or the

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[1] Jameson. Portland cement, p. 68.

Portland cements, is considerable (at least seven days, if a reasonably reliable indication is to be obtained), and, as work is usually carried on, is frequently impracticable. For this reason, short time tests are allowable in cases of necessity, though the most that can be done in such testing is to determine if the brand of cement is of its average quality. It is believed, however, that if a neat cement stands one day tensile test, and the tests for checking and fineness, its safety for use will be sufficiently indicated in the case of a brand of good reputation; for, it being proved to be of average quality, it is fair to suppose that its subsequent condition will be what former experiments, to which it owes its reputation, indicate that it should be. It can not be said that a new and untried cement will by the same tests be proved to be satisfactory; only a series of tests for a considerable period, and with a full dose of sand, will show the full value of any cement; and it would be safer to use a trustworthy brand without applying any tests whatever than to accept a new article which had been tested only as neat cement and for but one day only.

The test for compressive strength is a very valuable one in point of fact, but the appliances for crushing are usually somewhat cumbersome and expensive, so much so that it seems undesirable that both tests should be embodied in a uniform method proposed for general adoption. Where great interests are at stake, however, and large contracts for cement depend on the decision of an engineer as to quality, both tests should be used if the requisite appliances for making them are within reach. After the tensile strength has been obtained, the ends of the broken briquets, reduced to one inch cubes by grinding and rubbing, should be used to obtain the compressive strength. The adhesive test, being in a large measure variable and uncertain and therefore untrustworthy, is not recommended.

The strength of a cement depends greatly upon the fineness to which it is ground, especially when mixed with a large dose of sand. It is, therefore, recommended that the tests be made with cement that has passed through a no. 100 sieve (10,000 meshes to the square inch) made of no. 40 wire, Stub's wire gage. The results thus obtained will indicate the grade which the cement can attain, under the condition that it is finely ground, but it does not show whether or not a given cement offered for sale shall be accepted and used. The determination of this question requires that the tests should also be applied to the cement as found in the market. Its quality may be so high that it will stand the tests even if very coarse and granular, and, on the other hand, it may be so low that no amount of pulverization can redeem it. In other words, fineness is no sure indication of the value of the cement, although all cements are improved by fine grinding. Cement of the better grades is now usually ground so fine that only from 5% to 10% is rejected by a sieve of 2500 meshes per square inch, and it has been made so fine that only from 3% to 10% is rejected by a sieve of 32,000 meshes per square inch. The finer the cement, if otherwise good, the larger the dose of sand it will take, and the greater its value.

CHECKING OR CRACKING

The test for checking or cracking is an important one, and, though simple, should never be omitted. It is as follows: make two cakes of neat cement, 2 or 3 inches in diameter, about ½ inch thick, with thin edges. Note the time in minutes that these cakes, when mixed with water to the consistency of a stiff plastic mortar, take to set hard enough to stand the wire test recommended by Gen. Gilmore, 1/12 inch diameter wire loaded with ¼ of a pound, and 1/24 inch loaded with 1 pound. One of these cakes, when hard enough, should be put in water and examined from day to day to see if it becomes contorted, or if cracks show themselves at the edges, such contortions or cracks indicating that the cement is unfit for use at that time. In some cases the tendency to crack, if caused by the presence of too much unslaked lime, will disappear with age. The remaining cake should be kept in the air and its color observed, which, for a good cement, should be uniform; the Portland cements being of a bluish gray throughout, yellowish blotches indicating poor quality; and the natural cements being light or dark, according to the character of the rock of which they are made. The color of the cements when left in the air indicates the quality much better than when they are put in water.

TESTS RECOMMENDED

It is recommended that tests for hydraulic cement be confined to methods for determining fineness, liability to checking or cracking, and tensile strength; and for the latter, for tests of seven days and upward, that a mixture of one part of cement to one part of sand for natural cements, and three parts of sand for

Portland cements, be used, in addition to trials of the neat cement. The qualities used in the mixture should be determined by weight.

The tests should be applied to the cements as offered for sale. If satisfactory results are obtained with a full dose of sand, the trials need go no further. If not, the coarser particles should first be excluded by using a no. 100 sieve in order to determine approximately, the grade the cement would take if ground fine; for fineness is always attainable, while inherent merit may not be.

The following table, showing the average minimum and maximum tensile strength per square inch which good cements have attained when tested under the conditions specified elsewhere in the report, has been prepared by the committee. Within the limits given in the following table the value of a cement varies closely with the tensile strength when tested with the full dose of sand.

American natural cement, neat:

One day; one hour, or until set, in air, the rest of the 24 hours in water, from 40 to 80 pounds.

One week; one day in air, six days in water, from 60 pounds to 100.

One month (28 days); one day in air, 27 days in water, from 100 pounds to 150 pounds.

One year; one day in air, the remainder in water, from 300 pounds to 400 pounds.

American and foreign Portland cements, neat:

One day; one hour, or until set, in air, the rest of the 24 hours in water, from 100 to 140 pounds.

One week; one day in air, six days in water, from 250 to 550 pounds.

One month (28 days); one day in air, 27 days in water, from 350 to 700 pounds.

One year; one day in air, the remainder in water, from 450 to 800.

American natural cements, one part of cement to one part of sand:

One week; one day in air, six days in water, from 30 pounds to 50.

One month (28 days); one day in air, 27 days in water, from 50 to 80 pounds.

One year; one day in air, the remainder in water, from 200 to 300.

American and foreign Portland cements, one part of cement to three parts of sand:

One week; one day in air, six days in water, from 80 to 125 pounds.

One month (28 days); one day in air, 27 days in water, from 100 to 200 pounds.

One year; one day in air, the remainder in water, from 200 pounds to 350 pounds.

Standards of minimum fineness and tensile strength for Portland cement, as given below, have been adopted in some foreign countries. In Germany, by Berlin society of architects, Society of manufacturers of bricks, lime and cement, Society of contractors, and Society of German cement-makers.

Standard of 1877. Fineness, not more than 25% to be left on sieve of 5806 meshes per square inch.

Tensile strength, 1 part cement, 3 parts sand, 1 day in air, 27 days in water, 113.78 pounds per square inch.

Standard of 1878. Fineness, not more than 20% to be left on the sieve, as above.

Tensile strength, same mixture and time as above, 142.23 pounds per square inch.

In Austria, by Austrian association of engineers and architects.

Standard of 1878. Fineness same as German of 1878.

Tensile strength, same mixture as above, 7 days, 1 day in air, six days in water, 113.78 pounds per square inch.

28 days, 1 day in air, 27 days in water, 170.68 pounds per square inch.

In Austria a standard for the minimum fineness and tensile strength of Roman cement was established and generally accepted, as follows.

Standard of 1878. Fineness, same as Portland.

Tensile strength (1 part of cement, 3 parts of sand) for:

Quick setting (taking 15 minutes or less to set):

Seven days, 1 day in air, six days in water, 23 pounds per square inch.

28 days, 1 day in air, 27 days in water, 56.9 pounds per square inch.

Slow setting cement (taking more than 15 minutes to set):

Seven days, one day in air, six days in water, 42.6 pounds per square inch.

28 days, one day in air, 27 days in water, 85.3 pounds per square inch.

The Roman cements correspond to those classified in this report under the head of natural cements.

Standards have been adopted also in Sweden and Russia.

MIXING, ETC.

The proportions of cement, sand and water should be carefully determined, by weight, the sand and cement mixed dry, and the water all added at once. The mixing must be rapid and thorough, and the mortar, which should be stiff and plastic, should be firmly pressed with a trowel, without ramming, and struck off level; the molds in each instance, while being charged and manipulated, to be laid directly on glass, slate, or some other non-absorbent material. The molding must be completed before incipient setting begins. As soon as the briquets are hard enough to bear it, they should be taken from the molds and kept covered with a damp cloth until they are immersed. For the sake of uniformity, the briquets, both of neat cement and those containing sand, should be immersed in water at the end of 24 hours, except in the case of the one day tests.

Ordinary, fresh, clean water, having a temperature between 60 and 70° F, should be used for water of mixture and immersion of samples.

The proportion of water required varies with the fineness, age, or other conditions of the cement, and the temperature of the air, but is approximately as follows: for briquets of neat cement, Portland, about 25%; natural, about 30%. For briquets of one part cement, one part sand, about 15% of total weight of sand and cement. For briquets of one part cement, three parts sand, about 12% of total weight of sand and cement. The object is to produce the plasticity of rather stiff plasterer's mortar.

An average of five briquets may be made for each test, only those breaking at the smallest section to be taken. The briquets should always be put in the testing machine and broken immediately after being taken out of the water, and the temperature of the briquets and of the testing-room should be constant between 60 and 70° F.

The stress should be applied to each briquet at a uniform rate of about 400 pounds per minute, starting each time at 0. With a weak mixture one half the speed is recommended.

WEIGHT

The relation of the weight of cement to its tensile strength is an uncertain one. In practical work, if used alone, it is of little value as a test, while in connection with the other tests recommended it is unnecessary, except when the relative bulk of equal weights of cements is desired.

We recommend that the cubic foot be substituted for the bushel as the standard unit, whenever it is thought best to use this test.

SETTING

The rapidity with which a cement sets or loses its plasticity furnishes no indication of its ultimate strength. It simply shows its initial hydraulic activity.

For purposes of nomenclature, the various cements may be divided arbitrarily into two classes, namely; quick setting, or those that set in less than one half hour; and slow setting, or those requiring one half an hour or more to set. The cement must be adapted to the work required, as no one cement is equally good for all purposes. For submarine work a quick setting cement is often imperatively demanded, and no other will answer, while for work above the water line less hydraulic activity will usually be preferred. Each individual case demands special treatment. The slow setting natural cements should not become warm while setting, but the quick setting ones may, to a moderate extent, within the degree producing cracks. Cracks in Portland cement indicate too much carbonate of lime, and in the Vicat cements too much lime in the original mixture.

SAMPLING

There is no uniformity of practice among engineers as to the sampling of the cement to be tested, some testing every tenth barrel, others every fifth, and others still every barrel delivered. Usually, where cement has a good reputation, and is used in large masses, such as concrete in heavy foundations or in the backing or hearting of thick walls, the testing of every fifth barrel seems to be sufficient; but in very important work, where the strength of each barrel may in a great measure determine the strength of that portion of the work where it is used, or in the thin walls of sewers, etc., every barrel should be tested, one briquet being made from it.

In selecting cement for experimental purposes, take the samples from the interior of the original packages, at sufficient depth to insure a fair exponent of the quality, and store the same in tightly closed receptacles impervious to light or dampness until required for manipulation, when each sample of cement should be so thoroughly mixed, by sifting or otherwise, that it shall be uniform in character throughout the mass.

SIEVES

For ascertaining the fineness of the cement, it will be convenient to use three sieves, viz:

No. 50 (2500 meshes to the square inch), wire to be no. 35 Stub's wire gage.

No. 74 (5476 meshes to the square inch), wire to be of no. 37 Stub's wire gage.

No. 100 (10,000 meshes to the square inch), wire to be of no. 40 Stub's wire gage.

The object is to determine by weight the percentage of each sample that is rejected by these sieves, with a view not only of furnishing the means of comparison between tests made of different cements by different observers, but indicating to the manufacturer the capacity of his cement for improvement in a direction always and easily within his reach. Tests for strength should be applied to the cement as offered in the market, as well as to that portion of it which passes the no. 100 sieve.

For sand, two sieves are recommended, viz:

No. 20 (400 meshes to the square inch), wire to be of no. 28 Stub's wire gage.

No. 30 (900 meshes to the square inch), wire to be of no. 31 Stub's wire gage.

These sieves can be furnished in sets, as follows, an arrangement having been made with a manufacturer of such articles, by which he agrees to furnish them of the best quality of brass wire cloth, set in metal frames, the cloth to be as true to count as it is possible to make it, and the wire to be of the required gage. Each set will be inclosed in a box, the sieves being nested.

Set A, three cement sieves, to cost $4.80:

No. 100	7 inch diameter
No. 74	6½
No. 50	6

Set B, two sand sieves, to cost $4:

No. 30	8 inch diameter
No. 20	7½

STANDARD SAND

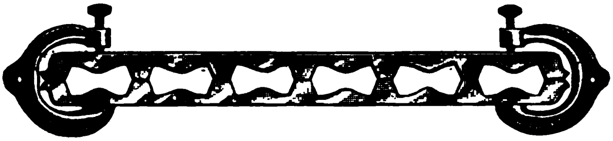
The question of a standard sand seems one of great importance, for it has been found that sands looking alike and sifted through the same sieves give results varying within rather wide limits.

The material that seems likely to give the best results is the crushed quartz used in the manufacture of sandpaper. It is a commercial product, made in large quantities and of standard grades, and can be furnished of a fairly uniform quality. It is clean and sharp, and, although the present price is somewhat excessive (3 cents per pound), it is believed that it can be furnished in quantity for about $5 per barrel of 300 pounds. As it would be used for tests only, for purposes of comparison with local sands, and with tests of different cements, not much of it would be required. The price of the German standard sand is about $1.25 per 112 pounds, but the article, being washed river sand, is probably inferior to crushed quartz. Crushed granite can be furnished at a somewhat less rate than quartz, and crushed trap for about the same as granite, but no satisfactory estimate has been obtained for either of these. The use of crushed quartz is recommended by your committee, the degree of fineness to be such that it will all pass a no. 20 sieve and be caught on a no. 30 sieve. Of the regular grade, from 15% to 37% of crushed quartz, no. 3 passes a no. 30 sieve, and none of it passes a no. 50 sieve. As at present furnished, it would need resifting to bring it to the standard size; but, if there were sufficient demand to warrant it, it could undoubtedly be furnished of the size of grain required at little, if any, extra expense.

A bed of uniform, clean sand of the proper size of grain has not been found, and it is believed that to wash, dry, and sift any of the available sands would so greatly increase its cost that the product would not be much cheaper than the crushed quartz, and would be much inferior to it in sharpness and uniform hardness of particles.

MOLDS

The molds furnished are usually of iron or brass, the price of the former being $2, and of the latter $3 each. Wooden molds, if well oiled to prevent their absorbing water, answer a good purpose for temporary use, but speedily become unfit for accurate work. A cheap, durable, accurate, and non-corrodible mold is much to be desired. Molds are made for holding one, two or more briquets. A common form is shown in pl. 27.



Brass mold for making cement briquets (Riehle Bros.)

CLIPS

For using the clips recommended in the preliminary report it was found in some instances that the specimens were broken at one of the points where they were held. This was undoubtedly caused by the insufficient surface of the clip, which, forming a blunt point, forced out the material. Where the specimens were sufficiently soft to allow this point to be embedded, they broke at the smallest section, but, when hard enough to resist such embedding, they showed a wedge-shaped fracture at the clips. To remedy this, the point should be slightly flattened, so as to allow of more metal surface in contact with the briquet. Clips made in this way have been used, and good results obtained.

To adapt the one inch clips of the Riehle machine, only a slight amount of work is necessary; the ends being rounded, will admit the proposed new form of briquet, and yet not prevent the use of the old one, thus allowing comparative tests of the two forms to be made without changing the clips.

There should be a strengthening rib upon the outside of the clips to prevent them from bending or breaking when the specimens are very strong.

The clips should be hung on pivots so as to avoid as much as possible cross strain upon the briquets.

MACHINES

No special machine has been recommended, as those in common use are of good form for accurate work, if properly used, though in some cases, they are needlessly strong and expensive. Machines with spring balances are to be avoided as more liable to error than others.

It is by no means certain that there exists any great difference in well made machines of the standard forms given.

AMOUNT OF MATERIAL

The amount of material needed for making five briquets of the standard size recommended is: for the neat cements, about one and two thirds pounds; and for those with sand, in the proportion of three parts of sand to one of cement, about one and one quarter pounds of sand and six and two thirds ounces of cement.

German specifications for standard Portland cement tests

Definition. Portland is a product resulting from the vitrification of a thorough mixture of material, whose principal component parts are lime and alumina, and the grinding of the vitrified material to a fine powder.

1 Packing and weights: As a rule Portland cement is to be packed in standard barrels of 180 kilograms (397 pounds), gross weight, and about 170 kilograms (374 pounds), net weight, and in half standard barrels of 90 kilograms (198 pounds), gross weight and about 83 kilograms (133 pounds), net weight. The gross weight is to be marked on the barrels. If the cement is called for in bags or barrels of other weight, the gross weight of the same must be clearly marked upon the packages. Losses and variations in weight of the single packages up to 2% of the same will be allowed. Barrels and sacks, in addition to the weight shall show in legible writing the name and trade mark of the manufacturer.

2 Time of setting: Slow or quick setting cement may be called for according to the use for which the cement is to be put. Cements which do not set in less than 2 hours, are to be considered slow setting cements.

3 Constancy of volume: Portland cement shall be of constant volume. As a preliminary test, admitting of forming a rapid opinion, the heating test is recommended. The decisive test shall be that a paste of neat cement made on a glass plate protected against drying and placed under water after 24 hours, shall not show after the lapse of a longer period of time any blowing cracks, or change of shape.

4 Fineness of grinding: Portland cement shall be so finely ground that a batch of the same shall not leave a residue of more than 10% upon a sieve of 900 meshes per square centimeter (5806 meshes per square inch). The thickness of the wire of the sieve shall equal half the space between the wires. For test 100 grams (3½ ounces) of cement shall be used.

5 Tests of strength: The cohesive power of Portland cement shall be determined by the testing of a mixture of cement and sand. The tests shall be both tensile and compressive, made according to a uniform method, with test pieces of the same form and cross-section, and with the same apparatus. At the same time a determination of the strength of the neat cement is to be recommended.

6 Tensile and compressive strength: Good slow setting cement, in the proportion of three parts by weight of standard sand to one part of cement shall have when tested, after 28 days' hardening (one in air and 27 in water), a minimum tensile strength

of at least 16 kilo. q. c. m. (16 kilograms per square centimeter, 227 pounds per square inch). The compressive strength shall be at least 160 kilo. q. c. m. (2270 pounds per square inch).

Cement which shows a higher tensile or compressive strength in many cases of a greater addition of sand, from this point of view, as well as on account of its greater strength for the same amount of sand, is entitled to a correspondingly higher price.

For slow setting cements the strength after 20 days is less in general than the one above specified, therefore, in giving the results of tests, the time of setting shall also be given.

The tests shall be made in the following manner.

To determine the time of setting cement, a slow setting neat cement shall be mixed three minutes, and a quick setting neat cement shall be mixed one minute with water to a stiff paste. A cake about 1.5 cm (.59 inch) thick, with thin edges, shall be formed of this paste on a plate of glass. The consistency of the cement paste for this cake shall be such that, when brought with a trowel on the plate, the paste will only begin to run toward the edges of the same after the paste has been repeatedly jarred. As a rule 27% to 30% water will suffice to give the necessary consistency to the paste. As soon as the cake is sufficiently hardened, so that it will resist a slight pressure of the finger nail, the cement is to be considered as having set.

For the exact determination of the time of setting, and for determining the beginning of the time of setting, which latter is of importance in the case of quick setting cements, since they must be worked up before they begin to set, a standard needle 300 grams (10 ounces) in weight and 1 square mm (.00155 square inch) in cross-section, is used. A metal ring 4 cm (1.575 inch) in hight and 8 cm (3.15 inches) clear diameter (inside) is placed on a glass plate, filled with cement paste of the above consistency and brought under the needle. The moment at which the needle is no longer capable of completely penetrating the cement cakes is considered the beginning of the time of setting. The time elapsing between this and the moment when the standard needle no longer leaves an appreciable impression on the hardened cake is considered the time of setting.

For making the heat test (3) a stiff paste of neat cement and water is made, and from this cakes 8 cm (3.15 inches) to 10 cm (3.94 inches) in diameter and 1 cm (.394 inch) thick are formed on a smooth, impermeable plate, covered with blotting paper. Two of these cakes, which are to be protected against drying, in order to prevent drying cracks, are placed, after the lapse of 24 hours, or at least only after they have set, with their smooth surfaces on a metal plate and exposed, for at least one hour, to a temperature of from 110° C to 120 (230 to 248 F) until no more water escapes. For this purpose the drying closets in use in chemical laboratories may be utilized. If, after this treatment, the cakes show no edge cracks, the cement is to be considered in general of constant volume. If cracks do appear, the cement is not to be condemned, but the results of the decisive test with the cakes hardening on glass plates under water must be waited for. It must, however, be noticed that the heat test does not admit of a final conclusion as to the constancy of volume of those cements which contain more than 3% of calcium sulfate (gypsum) or other sulfur combinations.

For making the final test, the cake made for the purpose of determining the time of setting, for slow setting cements, is placed under water after the lapse of 24 hours, but, at all events, not until after it is set. For quick setting cements this can be done after a shorter period. The cakes, especially those of slow setting cement, must be protected against drafts and sunshine until their final setting. This is best accomplished by keeping them in a covered box lined with zinc, or under wet cloths. In this manner the formation of heat cracks is avoided, which are generally formed in the center of the cake, and may be taken by an inexperienced person for cracks formed by blowing.

In order to obtain concordant results in the tests, sand of uniform size of grain and uniform quality must be used. This standard sand is obtained by washing and drying the purest quartz sand obtainable, sifting the same through a sieve with 60 meshes per square cm (387 per sq. inch), thereby separating the coarsest particles, and by removing from the sand so obtained, by means of a sieve of 120 meshes per square cm, the finest particles. The diameter for the wires of the sieve shall be .38 mm, and .32 mm respectively. Since not all quartz sand even under the same method of treatment, gives the same resulting strengths in the mortars, one must know whether the standard sand at one's disposal gives concordant results with the standard sand furnished by the German society of cement manufacturers and also used at the royal testing station at Berlin (Charlottenburg).

For each test, in order to obtain correct average results, at least six test pieces are to be made. Tensile test pieces can be made either by hand or by machinery.

HAND WORK

On a metal or thick glass plate five sheets of blotting paper soaked in water are laid, and on these are placed five molds wetted with water; 250 grams (8.75 ounces) of cement and 750 grams of standard sand are weighed and thoroughly mixed dry in a vessel. Then 100 ccm (100 grams or 35 ounces) of fresh water are added, and the whole mass thoroughly mixed for five minutes. With the mortar so obtained the molds are at once filled, with one filling, so high as to be rounded on top, the mortar being well pressed in. By means of an iron trowel 5 to 8 cm (1.96 to 3.14 inches) wide, 35 cm (13.79 inches) long, and weighing about 250 grams, the projecting mortar is pounded first gently and from the sieve, then harder into the molds until the mortar grows elastic, and water flushes to the surface. A pounding of at least one minute is absolutely essential. An additional filling and pounding in of the mortar is not admissible, since the test pieces of the same cement shall have the same densities at the different stations. The mass projecting over the mold is carefully taken off, and the test piece placed in a box lined with zinc, which is to be provided with a cover, to prevent a non-uniform drying of the test pieces at different temperatures. 24 hours after being made, the test pieces are placed under water, and care has to be taken that they remain under water during the whole period of hardening.

MACHINE WORK

After the mold, provided with a guide mold, has been clamped, by means of set screws, on the bedplate of the pounding machine, for each test, 180 grams of the mortar, made as above, are placed in the mold and the iron follower is set in. By means of Böhme's hammer apparatus, with a hammer weighing 2 kilograms, 150 blows are struck on the follower.

After the guide mold and follower have been removed, the test piece is scraped off, smoothed, taken with the mold from the bedplate and for the rest treated as for the hand work. By accurately following the directions given above, hand and machine work give well concording results. In all cases of doubt the machine work is to be decisive.

COMPRESSIVE TESTS

In order to obtain concordant values in compression tests at different stations, machine making is necessary. 400 grams of neat cement and 1200 grams dry standard sand are thoroughly mixed dry in a vessel, and 160 ccm of water are added thereto, and then the mortar is thoroughly mixed for five minutes. Of this mortar 850 grams are placed in the cubic molds, provided with guide mold, and the mold is then screwed on the bedplate under the pounding machine. The iron follower is placed in the form, and, by means of Böhme's trip hammer, 150 blows are struck, by a hammer weighing 2 kilograms.

After removing the guide mold and follower, the test piece is smoothed off, with the mold from the bedplate, and for the rest treated as for hand work, as given above.

MAKING TEST PIECES OF NEAT CEMENT

The inside of the molds is slightly oiled, and the same are placed on a metal or glass plate without blotting paper. 1000 grams of cement are weighed out, 200 grams of water are added, and the whole mass thoroughly mixed for five minutes (best with pestle). The forms are well filled (rounded), and then proceed as for hand work as given above. The molds can only be taken off after the cement has sufficiently hardened. Since, by the pounding in of the neat cement, test pieces of uniform consistency are to be obtained, for finely ground or quick setting cements, the amount of water must be correspondingly increased. The volume of water is always to be stated in giving the strength obtained.

TREATMENT OF TEST PIECES AT TIME OF TESTING

All specimens are to be tested directly after their removal from the water. Since the time of testing is of influence on the result in tensile tests, the increase of load shall be 100 grams per second. The mean of the four best results shall be considered the final tensile strength. In testing compression pieces, the pressure is always to be exerted on two side faces of the cube, but not on the bottom or top. The mean of the four highest tests shall be considered as the final compressive strength.

Abstract from French specifications for Portland cement

CHEMICAL ANALYSIS

The cement must not contain more than 1% of sulfuric acids or sulfids in determinable proportion. Cements containing more than 4% of ferric oxid, or in which the ratio of the combined silica and alumina to the lime is less than .44, are to be regarded as doubtful.

MIXING THE MORTAR

In mixing the mortar for testing, sea water is specified, and both air and water are to be maintained at a temperature of 15° to 18° C (59–64.4 F) during the continuance of the experiments. The quantity of water is ascertained by a preliminary experiment, and the four following tests are given as an indication whether the proportion of water added is correct:

1 The consistence of the mortar should not change if it be gaged for an additional period of three minutes after the initial five minutes.

2 A small quantity of the mortar dropped from the trowel on a marble slab from the hight of about .50 meter (1.64 feet) should leave the trowel clean, and retain its form approximately without cracking.

3 A small quantity of the mortar worked gently in the hands should be easily molded into a ball, on the surface of which water should appear. When this ball is dropped from the height of .50 meter (1.64 feet) it should retain a rounded shape without cracking.

4 If a slightly smaller quantity of water be used, the mortar should be crumbly and crack when dropped upon the slab. On the other hand the addition of a further quantity of water — 1%–2% of the weight of the cement — would soften the mortar, rendering it more adhesive, and preventing it from retaining its form when allowed to fall on the slab. It is recommended to commence with a rather smaller quantity of water than is ultimately required, and then to make fresh mixings with a slight additional quantity of water.

The mortar is to be mixed with a trowel for five minutes on a marble slab.

STRENGTH

The form of briquet and method of molding are the same as in the German specifications; the breaking section is 5 sq. cm (.775 square inch). Six briquets are broken after an interval of seven days, six after 28 days, and the remaining six after 84 days. The mean of the three highest figures of each series of tests is taken as the tensile strength of the cement under examination. The minimum strength specified for the neat cement in seven days is 20 kilograms per sq. cm (284.5 pounds per square inch); in 28 days, 35 kilograms per sq. cm (498 pounds per square inch); and at least 45 kilograms per sq. cm (640 pounds per square inch) at the end of 84 days. If, however, the strength in 28 days is not more than 5 kilograms per sq. cm (71.12 pounds per square inch) in excess of that at seven days, then it must be at least 55 kilograms per sq. cm (727.8 pounds per square inch) in 28 days, and in any case where this is not attained in 28 days it must be exceeded in 84 days.

Tests of cement mixed with sand are also specified. The standard sand is produced by crushing quartzite obtained from the quarries near Cherbourg, and sifting it through sieves of 64 and 144 meshes per sq. cm (413 and 929 meshes per square inch). That which remains between these two sieves is washed and dried, and constitutes the standard sand. 375 grams (13.25 ounces) of this sand is mixed with 125 grams (4.41 ounces) of cement, and water is added in the proportion of 12 parts by weight to 100 parts of sand and cement combined. The sand and cement are first carefully mixed in a basin or capsule, then the whole of the sea water is added at once, and the mixture stirred with a spatula for 5 minutes. At the expiration of seven days the strength of the sand cement briquets should be at least 8 kilograms per sq. cm (113.78 pounds) and in 28 days 15 kilograms per sq. cm (213.35 pounds per square inch). In 28 days the strength should exceed that at seven days by 2 kilograms per sq. cm (28.45 pounds per square inch). In 84 days the strength must be greater than at 28 days, and at least 18 kilograms per sq. cm (256 pounds per square inch). The 84 day tests are only considered indispensable for those cements which may have stood the two previous tests; but if, while the cement is in store, the 84 day tests should be unsatisfactory, it may be rejected.

FINENESS OF GRINDING

The degree of fineness to which the cement must be ground is not specified, it being considered that very fine grinding increases the strength chiefly during the duration of the tests, and that subsequent increase of strength is less with fine than with coarse cement.

TIME OF SETTING

This practically agrees with the German specifications. Any cement commencing to set in less than 30 minutes, or failing to commence to set within three hours is to be rejected; and the final set must have taken place within 12 hours. In each case the time is reckoned from the moment the water is poured on the cement.

Books relating to cement

The following list gives the titles of a number of works, which will enable those desiring it to obtain more detailed information concerning the technology of cement manufacture than it is possible to give within the limits of this report.

Butler, D. B. Portland cement: its manufacture, testing and use. N. Y. 1899.

Candlot. Ciments et chaux hydrauliques. Paris 1891.

Clarke, E. C. Experiments with Rosendale and Portland cements. (*see* Trans. Am. soc. civ. eng. Oct. 1893. Ap. 1885; also June 21 and Nov. 1885)

Cummings, U. American cements. Bost. 1898.

Gary, M. Raumbeständigkeit von zehn Portland cementen. Kgl. Tech. Versuchsanstalten. 1899. Erganz. heft 1.

Gilmore, Q. A. Limes, hydraulic cement and mortars. N. Y. 1872.

Giron, P. Methods of burning cement. (*see* Proc. Eng. club. Phil. July 1893, v. 10)

Heath, A. H. Manual of lime and cement. N. Y. 1893.

Jameson, C. D. Portland cement, its manufacture and use. N. Y. 1898.

Johnson, J. B. Materials of construction. N. Y. 1898.

Kuichling, E. On cement mortars. (*see* Appendix, Annual rep't exec. board of city of Rochester. 1887)

Le Chatelier, H. Procédés d' essai des matériaux hydrauliques. (*see* Annales des mines. 1893. 2:252; tr. in Trans. Am. inst. min. eng. Aug. 1893)

Lewis, F. H. Manufacture of hydraulic cement in United States. (*see* Min. ind. 6: 91)

Lord, N. W. Natural and artificial cement. (*see* Ohio geol. sur. 6: 671)

Michaelis, R. Hydraulischer mörtel und Portland cemente.

Newberry, W. B. & S. B. The chemistry of Portland cement. (*see* Cement and engineering news. 1897. 3: 85; 1898. 4: 5)

Richardson, C. Series of articles on lime and cement mortars. Brickbuilder. 1897 and 1898.

Schoch, C. Die moderne aufbereitung und wertung der mörtel materialien. Ber. 1898.

Smith, W. A. On cements. (*see* Min. ind. 1: 49)

Spalding, F. P. Hydraulic cement, its properties, testing and use. N. Y. 1897.

Stillman, T. B. Methods of testing cement. (*see* Jour. chem. soc. 15: 181; 16: 161, 283, 374)

Also has bibliography.

Wilkinson, P. Technology of cement plaster. (*see* Trans. Am. inst. min. eng. 37: 508)

Zwick, A. Hydraulischer Kalk und Portland cement. Leipzig 1892.

GEOLOGY OF NEW YORK LIMESTONES

Limestones are found in New York from the oldest to the youngest formations. Some, like those of the pre-Cambrian, are often local in their extent; while others, like those of the Helderberg, extend from one end of the state to the other.

The formations containing limestone in New York state are the pre-Cambrian, Calciferous, Chazy, Trenton, Clinton, Niagara, Onondaga, Lower Helderberg, Upper Helderberg, Goniatite, Tully, Quaternary marls.

The most important of these are the Calciferous, Trenton, Niagara, Lower Helderberg and Upper Helderberg. The Calciferous and Niagara sometimes contain sufficient magnesia to be called true dolomites, and this fact, together with the freedom from impurities which they exhibit at some localities, gives them a special usefulness.

Calciferous

The rock of this formation is frequently highly magnesian, and a high percentage of silica is likewise not uncommon in it. On this account it is sometimes called Calciferous sandrock.

The Calciferous limestones occur as isolated patches or belts in several parts of the state, and show considerable variation in character. With few exceptions they are magnesian and indeed may pass into true dolomites. On the other hand, they are often highly silicious, so much so as to render them practically worthless for any of the uses considered in this report. Again they may run very low in silica, as near Glens Falls.

Cambro-Silurian limestones appear in the southeastern portion of the state in Orange county, extending northeastward across the county to the Hudson river, and across it through Dutchess into Columbia county.

Another series of belts begins in Westchester county and extends from New York city northward to the county line and through Putnam and Dutchess counties to Pawling and beyond.

The character of these is mentioned in the county descriptions. These limestones are equivalent to the Stockbridge, and represent the Acadian-Trenton periods.

A belt of Calciferous limestone extends from Saratoga westward through Montgomery, Fulton and Herkimer counties.

With the exception of the outcrops in the vicinity of Glens Falls the rock is usually very silicious and is known as sandrock.

In Herkimer, Fulton, Saratoga and Montgomery counties this formation underlies a considerable area and often forms cliffs along the rivers and creeks. Its normal character is fairly constant, viz a light bluish gray, fine grained, massively bedded sandy limestone. The weathered surfaces are generally a dirty buff. The following localities are noted by N. H. Darton as affording good exposures.[1]

About Middleville, Little Falls and northwestward along the fault scarp, on East Canada creek, about St Johnsville, along the Mohawk from Canajoharie to the 'Noses,' the quarries at Tribeshill along the Mohawk from Amsterdam to Hoffmanns ferry, also in southwestern Saratoga county and west of Saratoga Springs.

According to Walcott[2] the section of Calciferous near Saratoga involves:

	Feet
Massive layers of steel gray, more or less arenaceous limestone	125
Massive bedded, slightly magnesian, gray and dove colored limestone	35
Unfossiliferous, impure, compact, more or less silicious limestone	95
Dark gray, evenly bedded limestone	50
Oölitic limestone	30

Chazy

The Chazy limestone first appears at Saratoga and extends northward along the Champlain valley to Montreal. The area is probably a continuous one, though not exposed at all points. The most prominent exposures of the Chazy are in the quarries of the Chazy marble lime co. and William Goss, and at Grand Isle. The rock is a gray, subcrystalline limestone, and affords an excellent lime. The average thickness of the formation according to Brainerd and Seely is about 700 feet. The character of the stone is quite uniform. The Chazy limestone is not found in the Mohawk valley and thins out in the central and western part of the state.

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[1] 13th an. rep't N. Y. state geol. p. 612.

[2] Bul. 81. U. S. geol. sur. p. 346.

An analysis of the Chazy limestone from the quarry of the Chazy marble lime co. at Chazy, shows the high degree of purity of this limestone which is used in the manufacture of lime.

Silica	.72
Ferric oxid and alumina	.39
Lime	53.9
Magnesia	1.44
Carbon dioxid	43.92
	100.37

The stone is also available for the manufacture of Portland cement.

Trenton

The Trenton limestones involve several different members, viz, Birdseye, Black river and Trenton, the last being the uppermost. The most southern area is a small patch of impure, fossiliferous limestone along the river road four miles north of Newburgh.

An important belt extends southward along the Champlain valley, then along the Mohawk to Little Falls and thence northwestward to Watertown. Beds of the same age also occur east of Lake Champlain and extend southward into Washington county.

In this belt they are often metamorphosed or folded, but along the lake shore, specially along the margin of the Adirondack island of crystalline rocks, the beds are little disturbed and sometimes highly fossiliferous. The Birdseye rarely exceeds 6 feet in thickness. It is a pure dove colored to dark gray limestone with conchoidal fracture and often containing veins of quartz or calcite.

The total thickness of the Trenton in the Champlain valley is 230 feet, and it overlies the Chazy. Quarries have been opened up at Isle La Motte, Plattsburg, Larrabees point, and Crown point.

The Black river limestone in the Champlain valley is locally known as Isle La Motte marble. It has a varying thickness from 35 feet on Larrabees point to 75 feet on Crown point and 20 feet at Plattsburg. The stone is usually heavy bedded, tough, compact and black.

The Trenton proper is exposed at Crown Point (N. Y.) where it has a thickness of 150 feet. It is usually thin bedded and shaly but contains several beds of purer limestone.

Beginning at a point about one half mile south of Smiths Basin in Washington county, the Trenton limestone extends northward, passing east of North Granville, east of Whitehall, which lies on the western edge of the belt, then northward in a belt from one mile to half a mile wide, past Benson Landing and northward into Vermont. The town of Vergennes lies on the eastern border of the belt. Another belt of this same rock is found farther south in Washington county, extending from a point half a mile north of Easton Corners up to and for half a mile north of Argyle. Throughout its extent the rocks of these two more or less continuous belts have been highly disturbed by dynamic forces. They are much folded and crushed and at times assume a very slaty structure. The limestone is generally fine grained and of a black color, is traversed by numerous veins of white calcite and is frequently of high purity. It is mined at Smiths Basin and also west of Fairhaven on the Vermont line. At both of these localities the stone has been quarried for limemaking and flux.

In the Mohawk valley only the Birdseye and Trenton members are present. The Birdseye member is in greater part a fine grained, dove colored stone, and weathers light gray, and the beds are generally moderately heavy. The exposures are common in the Mohawk valley and have been quarried at a number of localities. Underlying this rock is the Calciferous sandstone.

According to Darton[1] the formation reaches its maximum thickness at Fort Plain, where it is about 9 feet thick. It then decreases westward to 7 feet near St Johnsville. It is 5 feet on East Canada creek, 4 feet around Little Falls and to the southeastward, and 5 to 6 feet on West Canada creek about Middleville, Newport and Cold creek.

At Ingham Mills the rock is well exposed in Butler's lime quarry. At this point nearly 15 feet of a good grade of stone is exposed. At Canajoharie the Trenton member of the group appears. Excellent exposures occur near Amsterdam and at Glens Falls. At this latter locality the quarries are of special importance. The Trenton limestone member is found extending eastward from Oneida county to Glens Falls. At times the rock is massive as at Tribeshill, at others it is somewhat shaly. The thickness in the quarries at Tribeshill is 12 to 14 feet of massive stone. Other exposures also occur in the quarries about Amsterdam and again in quarries 2 miles northwest of Hoffmans ferry, where about 20 feet of a soft, highly fossiliferous limestone is exposed.

A belt of Trenton occurs west of Saratoga and is well exposed at Howland's mill 3 miles due west — southwest from Saratoga Springs. The section here shows 20 feet of limestone.

At Glens Falls the Trenton limestone is well exposed on both banks of the Hudson, and is of much importance, being used for building stone lime and Portland cement.

Darton gives the following section of it.

	Feet
Thin bedded black limestones in beds 3 to 8 in.	10
Black marble 10 to 14 in. beds.	3

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[1] 15th an. rep't N. Y. state geol. p. 516.

	Feet
Black marble one or two in. beds	13
Black, massive, fine grained limestone. In floor of quarry	3
Dark gray, fine grained limestone	25
Black, compact limestones with slaty layers.	

It overlies the Chazy. There are also extensive outcrops of it around Hoosick Falls, but at this point the stone is apt to be slaty.

The Trenton rocks also extend northward from the Mohawk valley to Watertown. They are quarried at Prospect, Oneida, Port Leyden, Boonville and Watertown. The Trenton limestone formation is dark gray to black and is often fossiliferous. The central part of the Trenton formation is apt to be shaly in places, while the Birdseye limestone is massive and heavy bedded. The upper part of the Trenton formation or Trenton limestone proper is a lighter gray limestone and finely crystalline in its nature. This member is quarried at Prospect.

Niagara

In Schoharie county we find the eastern end of this formation. Its thickness is not more than 5 feet, and it is usually a dark gray, massive limestone. An exposure of it can be seen at Howe Cave just below the cement quarries, of which it forms the floor.

The Niagara limestone also appears in Oneida county north of Clayville and extends westward with increasing width to the Niagara river. In Wayne county in the town of Butler[2] it is a dark blue, fine grained, compact limestone and is usually thin bedded. It has been used at this point for burning lime. Other occurrences are at Rose on the head waters of Sheldon creek and in the towns of Marion and Walworth. It has been quarried at many points in Wayne county for the manufacture of lime.

In Monroe county the northern edge of the limestone passes through the towns of Penfield, Brighton, Gates, Ogden and

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[1] **Darton, N. H. Helderberg limestones and associated formations in eastern New York. (*see* 18th an. rep't N. Y. state geol. p. 218)**

[2] **Hall, James. Geol. 4th dist. N. Y. p. 84.**

Sweden. The outcrops at these points generally represent the beds of the upper magnesian member, and its weathered surface presents a characteristic spongy appearance.

The Niagara formation presents two types of lime rock: the one a dark gray, subcrystalline stone, which is used for lime and building purposes, the other a gray brown, crystalline rock with numerous cavities and containing a high percentage of magnesia.

The area in which the Niagara limestone is found is more restricted than that of most of the other limestone formations of the state. The upper member of this formation is known as the Guelph limestone but is not coextensive with the lower member. It forms a lenticular bed about 20 miles long and extends from Rochester westward. In the vicinity of Rochester quarries have been opened in it at New Brighton and Gates. As exposed in these quarries, it is a grayish brown, finely crystalline limestone containing numbers of small cavities. The peculiar feature of this rock is that it contains a large amount of magnesia and a very low silica percentage, making it very adaptable for use in the lining of Bessemer converters.

Lower Helderberg

This formation as formerly described includes several distinct members which are known as the Tentaculite, Waterlime, Pentamerous, lower or Catskill shaly, Becraft or upper Pentamerous, and upper shaly. The formation is a widely distributed one within the state and of considerable economic importance, containing the hydraulic limestones which are extensively developed at Rosendale near Kingston in Ulster county.

In his recent classification[1] Dr J. M. Clarke considers the Tentaculite limestone, which in this bulletin is discussed as the base of the Lower Helderberg, to be the highest member of the Salina. If Dr Clarke's grouping be accepted, then the most westerly outcrops of the Lower Helderberg in this state are in the neighborhood of Chittenango Falls, Madison co.; and the statements in the text should be correspondingly qualified.

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[1] **Mem. 3. N. Y. state mus.**

The members of this formation enter the state at the southeastern corner just east of Port Jervis (N. Y.) following up the southeastern side of the Neversink river, Bashers kill, and Rondout creek, throughout this whole distance resting on the Shawangunk grit which forms the crest of the Shawangunk mountain. From Kingston the same formation extends northward past Catskill to New Baltimore, where it then swings to the northwest, extending as far as New Salem in Albany county. At this point it becomes very narrow; it however appears again as a somewhat broad belt just west of Meadowdale in the same county and then extends westward as far as Central Bridge in Schoharie county, and from there in a slightly northwest direction past Sharon Springs, Dennisons Corners, Oneida, Syracuse, and westward to Niagara Falls. Up to Dennisons Corners the formation, though of considerable thickness, does not cover a very broad belt, owing to the perpendicular escarpment which it forms, but its thickness remains about the same from Syracuse westward to Buffalo, and the elevation of the escarpment decreases.

The Tentaculite limestone forms the lower member of the series and is generally a dark colored, thin to thick bedded, at times argillaceous limestone. It seldom reaches a condition of great purity and aside from the cement beds which are worked separately its chief use has been for building purposes.

As the Helderberg limestones are of considerable thickness in New York state, it may be well to mention them in detail. This can best be done by quoting from the report of N. H. Darton.[1]

The Helderberg limestones attain their greatest development in eastern New York, and the thickness reported by Davis of about 300 feet in the Catskill region is the maximum. They thin gradually southward in New York, but expand again in New Jersey. In the Helderberg mountains there are 200 feet and at

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[1] Report on the relations of the Helderberg limestones and associated formations in eastern New York. (*see* 13th an. rep't N. Y. state geol. p. 204)

Schoharie not over 240 feet. Westward from Schoharie the thickness decreases very gradually. The members constituting the formation in its typical development, beginning at the top, are a pure semicrystalline, massive, very fossiliferous limestone, a thick series of shaly limestone, and the basal series, thin bedded dark limestones of the Tentaculite beds. On Catskill creek a higher member of impure shaly limestone comes in above the pure, massive beds, thickens rapidly and continues southward to and through New Jersey. The Helderberg formation preserves its typical characters with some local variations in thickness to a few miles west of Cherry Valley. Then the upper limestone beds thin out, and on the road from West Winfield to Litchfield, in the southwestern corner of Herkimer county, the Pentamerus beds lie directly under the Onondaga limestone . . . The upper members of the Helderberg limestones . . . come in again westward and are finely exposed at Oriskany Falls.[1]. .Here 120 feet of beds are exposed in and about the quarries, of which 50 feet are quite distinctively of the Tentaculite beds, 40 feet of gray beds in greater part of Pentamerus limestone age, but merging into the character of the lower beds, a few feet of beds with mixed Pentamerus and shaly limestone fauna, and, at the top, 25 feet of gray subcrystalline rock containing a shaly limestone fauna. 25 miles west of Perryville, Madison co., this condition has continued, the lower members expanding apparently at the expense of the Pentamerus beds and the upper members giving place to Pentamerus beds. At this locality the Onondaga limestone was seen lying on a few feet of dark gray limestones containing Pentamerus, with a thin local intervening layer of Oriskany at one point, which gave place to a great mass of thin bedded gray limestone below.

The different members preserve their distinctive characters more or less, though there are occasional slight local variations.

The so-called Scutella beds are the uppermost member southward to near Catskill. They are light colored, coarsely semicrystalline, massively bedded, highly fossiliferous limestone blotched with calcite replacement of fossils, of which the most conspicuous is the so-called Scutella. These are the cups or pelvis of a crinoid, having a diameter in greater part from one to two inches, and the white calcite of which they consist contrasts strongly with the light bluish gray of the containing limestone. In the Schoharie region where these cups characterize the lower beds of the member, the overlying layers have been called the upper Pentamerus beds from the fossil P. pseudogaleatus which they contain, and this name has been employed to some extent to comprise all the beds. In the eastern extension of the formation the distinction is lost. About Catskill, Davis designates the lower layers the " Encrinal " and the upper layers the " upper Pentamerus " limestone. Owing to the inappropriateness of the name Scutella and the varying significance of the other names that have been employed, the geographic name of Becraft limestone has been suggested to me by Prof. Hall. The name is from Becraft mountain in Columbia county, where the rock is typically developed The Becraft limestone has a thickness of 10 to 15 feet near Schoharie, and the amount does not vary greatly eastward to the Helderberg mountains and by Clarksville, Aquetuck and Coxsackie. Thence it increases rapidly, and Davis reports a thickness of 120 feet below Leeds, the upper 10 feet consisting of impure and sandy or shaly layers. There are, as Davis suggests, many local slips in this section, and my estimate of the thickness of the purer limestone would be about 60 feet.

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[1] *See also* Williams, S. G. The westward extension of rocks of the Lower Helderberg age in New York, Am. jour. sci. 3d ser. 31: 139–45; abstract Proc. Am. ass'n adv. sci. 34: 235, 236; Am. nat. 1886. 20: 373.

" In the Rondout region the Becraft limestone is 40 feet thick and the upper shaly beds 100 to 150 feet thick. In the ridge just east of Whiteport there are 30 feet of Becraft limestone." About Rosendale and southward no exposures have been noted by Darton. " Underlying the Becraft limestone throughout are the lower shaly beds, consisting of thin bedded, impure, highly fossiliferous limestone with some shale beds." At some localities though, as for instance westward on the Fox kill above Gallupville, it is in greater part a massive, relatively pure limestone. In Greene and Ulster counties it has the character of the upper shaly beds, with a more or less slaty cleavage and outcropping in ragged ledges, in some cases closely resembling the lighter colored outcrops of the Esopus slate. Its thickness from Schoharie eastward is about 80 feet, and there and elsewhere in the great Helderberg escarpment it constitutes a steep slope between the Scutella and Oriskany shelf above the Pentamerus escarpment below. Its thickness apparently decreases somewhat in the Kingston-Rosendale region, but it retains its characteristics.

The Pentamerus or lower Pentamerus are the most conspicuous members of the lower Helderberg formation. They give rise to the great escarpment which marks the eastern edge of the Helderberg formation as it passes along through central New York.

The beds are mostly hard, massively bedded and vertically jointed limestones. The rock is generally bluish gray in color but weathering imparts a lighter tint to the surface. Partings of slate occur occasionally as well as lenses of chert, specially in the east and south.

The Pentamerus limestone is a quite uniform member, and its thickness does not vary greatly. "At Schoharie its thickness is between 60 and 70 feet, in the Helderbergs it is the same and a trifle more about Catskill, 80 feet according to Davis, 50 feet at Saugerties, 30 to 40 feet about Rondout, 70 to 100 feet about Rosendale, the maximum being in the ridge just northwest of the village. The Pentamerus beds are quite sharply demarked from those above and below them."

The finest exposures of the Pentamerus ledges are in the great escarpment of the Helderberg mountains near the Indian Ladder, where they rise in great cliffs surmounting steep slopes to an altitude of 700 feet above the plain lying to the north and east.

The Tentaculite beds are thin bedded, dark blue limestones, lying below the Pentamerus beds, and usually constituting the base of the Pentamerus escarpment or lying beneath its talus. The beds vary in thickness from an inch to a foot in greater part, but two or three inches is the average.

The Tentaculite beds have a thickness of 40 feet at Howe Cave and Schoharie, somewhat less in the Helderberg mountains and from 30 to 40 feet through the Catskill and Kingston regions. In the Rosendale region the amount is less.

There are several outliers of the Helderberg limestone, of which an important one is Becraft mountain.

The attenuated eastern extension of the great Salina formation is of variable character and thickness and may not be continuous throughout. Locally it consists of heavy beds of cement rock but generally it is composed of thin beds of more or less impure cement intercalated with thin bedded limestones of varying character.

"The cement beds attain their greatest development around Rondout and Rosendale, where they are extensively worked. The cement rock is a blue black, very fine grained, massively bedded deposit of calcareous magnesian and argillaceous materials and is of somewhat variable character and composition. The rock produces a cement of good quality only when the components bear certain relative proportions to each other. A characteristic feature of the rock is the light buff hue to which it weathers on the surface. At Rosendale there is a 21 foot bed of the cement at the base of the formation, then from 12 to 15 feet of mixed impure cement and limestone beds, then another cement bed 11 feet in thickness. Above these are the Tentaculite and Pentamerus.

These cement beds with some variations in thickness, and many in character, extend over a wide area from north of Whiteport through Rosendale to beyond Highfalls, outcropping in a belt about eight miles long and two and a half wide. At Highfalls there is an upper bed of cement, 15 feet thick and a lower bed 5 feet thick, separated by 3 feet of impure limestone. At Whiteport the upper cement bed is 12 feet thick, the lower from 15 to 20 and the intervening limestone 10 feet in thickness. How far they may extend under the overlying rocks to the westward is not known, and their southern termination has not been explored. To the northeast the cement thins out rapidly and gives place to impure cements and limestones, but it thickens again rapidly in the Rondout region. At Rondout there are two cement beds, the lower one is 22 feet thick and the upper 5 feet thick, with 3 feet of limestone and cement intervening. Northwest the lower cement bed thins.

In Onondaga county the cement beds are again prominent, and vary in thickness from 1 to 5 feet. Many of the quarries show two beds."

Upper Helderberg

This is the limestone series which is termed the Corniferous by many writers, but by others the upper member of the series is termed Corniferous and the lower member Onondaga. The formation usually rests on the Schoharie grit, Cauda Galli grit, or Oriskany sandstone, but in the western part of the state these are wanting. The formation is divisible into 3 members, viz:

1 The lower, or Onondaga graystone, which is coarsely crystalline and well adapted for building.

2 The Corniferous, which is a hard and durable limestone containing many chert nodules.

3 The Seneca blue limestone, the purest of the three, fine grained and dark blue.

The upper Helderberg rocks are quarried near Kingston, Ulster co., at Splitrock, near Syracuse, also at Auburn, Waterloo, Seneca Falls, Leroy, Williamsville and Buffalo.

The subdivisions of the Onondaga group gradually lose their physical and faunal characteristics in eastern New York, and the formation is in greater part a bluish gray subcrystalline, massive limestone with lenticular masses of chert in courses and irregularly disseminated. Darker colors occur locally, notably in the upper beds about Peoria (West Berne), which are very dark and coarsely crystalline. The chert is predominant in the upper beds, but it is usually present also in the lower beds. In places it is an inconspicuous feature but this is not often the case. Thin partings of shale occur rarely. About Saugerties the lower portion of the limestone is shaly and weathers buff. About Clarksville the lower members are very pure, free from chert and regularly bedded.

In Greene and Ulster counties particularly the outcropping edge of the formation is characterized by a fringe of very large disconnected blocks occurring at various intervals. In some cases these blocks lie several hundred yards from the edge of the outcrop.

Goniatite

This is a local layer of limestone found near the base of the Hamilton group in Onondaga county. Westward in Genesee county at the village of Stafford it is called the Stafford limestone, and extends from there to Lake Erie.

Tully

This is the most southern limestone formation found in any part of New York except Orange and Westchester counties, and the limestone of those counties is largely dolomitic. It forms a layer about 10 feet thick at the top of the Hamilton group, and derives its name from its type occurrence at the village of Tully in Onondaga county. It is rather local in its extent, and does not occur in the eastern or western part of the state, extending only from Ontario to Madison. Few quarries have been opened in it, and it has only been extracted at times for purely local wants.

Excellent exposures of it occur however on the shores of both Cayuga and Seneca lakes, and the material could be easily quarried at these places.

Quaternary marls

These represent the only unconsolidated types of limestones found in New York. The deposits are usually found underlying swampy areas, specially in the central portion of the state between Syracuse and Rochester, being commonly underlain by clay, and overlain by muck.

The origin of these marls is a matter of much interest. While the marl is sometimes spoken of as "shell marl", at the same time the shells found in it form but a very small part of the whole, the greater portion being made up of granular carbonate of lime, and the probable cause of accumulation is by precipitation from calcareous waters, the snails being found in the marl because they frequent water carrying lime.

Central New York contains an abundance of calcareous rocks, and fragments from them are also found in the drift, so that there is abundant opportunity for the carbonated spring waters to take carbonate of lime in solution. This is taken in solution in the form of a bicarbonate which, when exposed to the air, is very unstable, so that the lime is precipitated on the emergence of the water as a spring. Temperature may also effect the result, in that the lime carbonate is more insoluble as the temperature of the water rises. This cause has been argued for by I. C. Russell[1] as explaining the formation of marl deposits in Michigan. The marl, as it precipitates, settles not only on the bottom of the pond, but also on the grasses around the edge. This method of formation is observable in the kettle hole ponds in the terminal moraine near Cortland, New York. The effect of certain plants on the precipitation of carbonate of lime was referred to earlier in the report.

In this state the marl deposits are known to occur in the swampy areas near Warner and Jordan, Onondaga co.; in the valley from Wayland to Perkinsville, Steuben co.; Caledonia, Livingston co.; northwest of Canastota, Oneida co.; Cassadaga, Chautauqua co.; Cortland, Cortland co.; Clifton Springs, Ontario co.; Clarendon, Orleans co.; Bergen, Genesee co.; near Chittenango Falls, Madison co., etc. The associations and extent of these deposits vary, as does also the purity of the marl. In addition to these localities Beck also states that marl occurs at the following ones: 2 miles southeast of Lodi on branch of Cattaraugus creek, Cattaraugus co.; in Schuyler county, at Beaver Dams in town of Dix, near Horseheads and near Millport, Chemung co.; in Columbia co., 4 miles north of Kinderhook; in Dutchess co., towns of Rhinebeck, North East, Pine Plains, Stanford and Red Hook; Montgomery co., near Canajoharie, Fort Plain and Fonda; Niagara co., along Tonawanda creek, and in swamp 5 miles east of Lockport; Otsego county, in southern part of Cherry Valley township. Unless the area of marl is large, and this would be indicated by the size of the swampy tract, which it underlies, it does not pay to work it for any purpose requiring large quantities of raw material.

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[1] Bul. 10. Geol. soc. Am. 1899.

It seems curious that the sole application of this material which usually suggests itself is for the manufacture of Portland cement, and, while this is indeed an important application, still it is only worthy of consideration in the case of very large deposits, that is, those not less than 6 feet thick and of at least 100 acres area, while deposits smaller than this are open to nearly all the uses to which limestone can be put.

LIMESTONE OCCURRENCE BY COUNTIES[1]

In the following descriptions it has been attempted to give as far as possible the occurrence and extent of the different limestone formations in each county, together with their characters. As many analyses as possible have been collected, and a number of additional ones made for the report. Reports of an economic nature are rare, but a number of county and locality reports have been issued, the titles of papers and reports relating to the region being given. Where the report contains analyses, it is marked with an asterisk (*), and reports of an economic nature are also preceded by a dagger (†).

Albany county[2]

The only limestone formations in this county are the Lower Helderberg and the Corniferous. The former are specially conspicuous, as they form the Helderberg escarpment, which in this county reaches its greatest elevation.

Onondaga limestone. In Albany county, this formation appears as a terrace extending along the foot of the slopes formed by the Hamilton shales. In the northeastern face of Helderberg mountain the outcrop is narrow, but it widens to the westward, being a mile and a half at Thompsons lake, and after narrowing it again becomes 3 miles wide in the long slopes northwest of Berne. The formation in this county is a light bluish gray, tough, massive limestone, quite pure but containing lenses of chert, which are chiefly abundant in the lower beds. At times it disappears altogether, but this is not usual. One of the best ledges of Onondaga limestone is in the cliffs near Oniskethau creek at Clarksville.

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[1] *General articles on New York limestones*

Hall, James. County reports. (*see* Geol. 4th dist. N. Y.)

Merrill, F. J. H. Mineral resources of New York state. (*see* Bul. 15. N. Y. state mus.)

——— Guide to the study of the geological collections. (*see* Bul. 19. N. Y. state mus.)

Merrill, G. P. Stones for building and decoration.

Ries, H. Report on limestones of eastern New York and western New England. (*see* 17th an. rep't U. S. geol. sur., chapter on limestone)

Smock, J. C. Building stones in New York. (*see* Bul. 3 and 10. N. Y. state mus.)

[2] Darton, N. H. Report on relations of Helderberg limestones in eastern New York. (*see* 13th rep't N. Y. state geol. 1893. p. 197–228)

——— Preliminary report on the geology of Albany co. (*see* 47th an. rep't N. Y. state mus. p. 425–55)

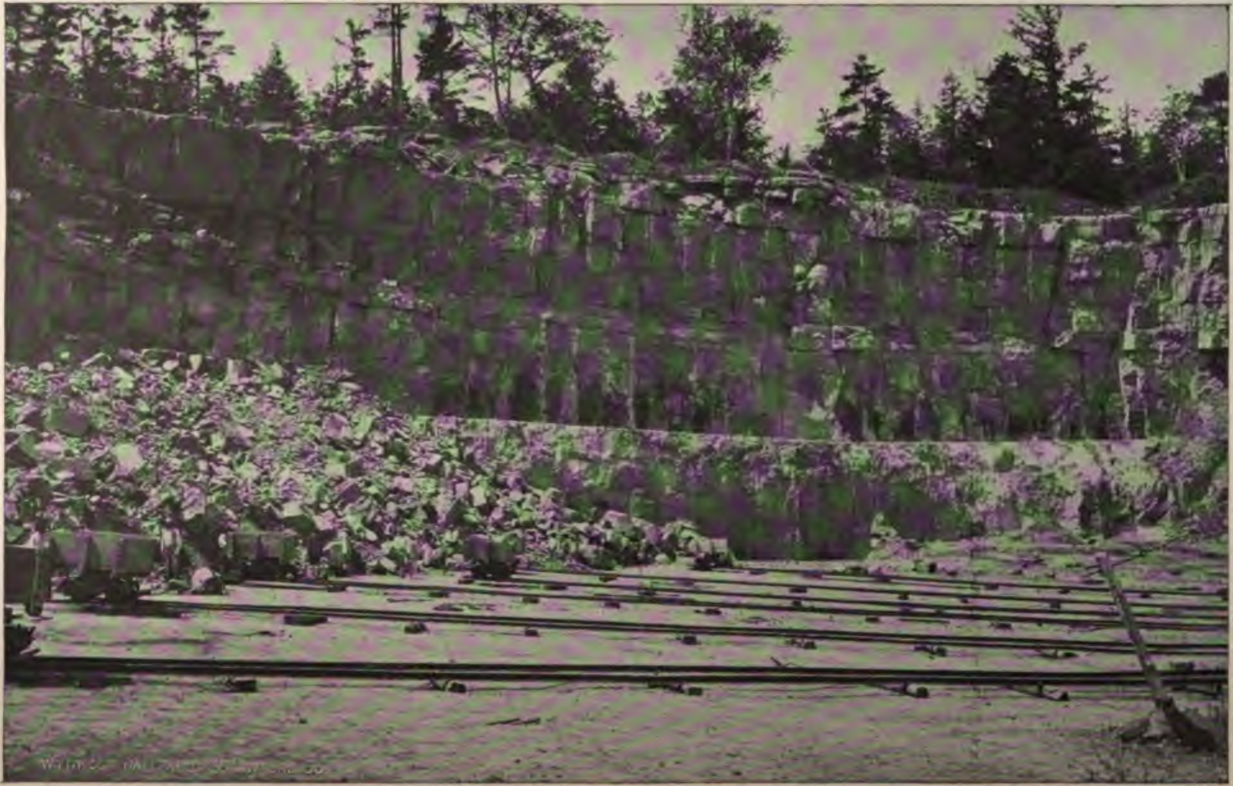
*† Nason, F. L. Economic geology of Albany county. (*see* 13th an. rep't N. Y. state geol. 1893. p. 263–87)

Mather, W. W. Geol. 1st dist. N. Y. 1843.

Lower Helderberg limestone. This reaches a large development in Albany county and is divisible into several well marked members. The foremost of these is the Becraft, also known as the Scutella limestone. This rock is of light color, often crystalline and full of fossils. Its average thickness in Albany county is about 15 feet, and its composition may be inferred from an analysis given of the same bed occurring at Rondout, Ulster co., and Hudson, Columbia co. One exposure of it is in the creek bed south of Callanans Corners. Underlying the Becraft limestone is a series of different beds, of very impure, highly fossiliferous, shaly limestone of a gray and grayish brown color and probably too impure for any use except building or road-making. Their thickness averages 100 feet. Under these, however, comes the Pentamerus limestone, which is an important member of the Helderberg formation, whose outcrop is marked by lines of prominent cliffs. It is usually cracked, and its color is that of a red, bluish gray limestone, which is of a lighter color on the weathered surface. The beds are often cut by vertical joints and there may be occasional layers of shale. The Pentamerus limestone in Albany county has an average thickness of 65 feet. It is a well known formation and has been quarried for lime at numerous points throughout the state. One of the best exposures of this stone is at the Indian Ladder. Underlying the Pentamerus bed is a series of thin bedded, dark blue limestones, which generally crop out at the base of the Helderberg escarpment but are frequently hidden by the talus at the base of the cliff. These Tentaculite limestones are often of a shaly nature. Their thickness along the eastern face of Helderberg mountain according to Darton is about 30 feet. They are also exposed at the Indian Ladder and at South Bethlehem. An excellent section of both Pentamerus and the

Plate 28

To face p. 771



H. Ries, photo.

Quarry in Lower Helderberg limestone. South Bethlehem, Albany co.

Tentaculite bed, is seen in Callanan's quarry southwest of South Bethlehem (pl. 28), analyses of which are given below. Underlying the Tentaculite are the Waterlime beds, also exposed at Indian Ladder and in the floor of the quarry at South Bethlehem, and at both localities they are about four feet thick and represent impure magnesia limestones.[1]

The following analyses made for this report will indicate the character of limestones of the Helderberg series in Callanan's quarry at South Bethlehem.

Lower third of quarry

Silica	9.05
Ferric oxid	.99
Alumina	6.66
Lime carbonate	79.86
Magnesia carbonate	4.17
	100.73

Middle third

Silica	5.12
Alumina	1.45
Ferric oxid	.74
Lime carbonate	48.34
Magnesia carbonate	2.93
Carbon dioxid	41.22
	99.8

Upper third

Silica	11.16
Ferric oxid	1.15
Alumina	3.35
Lime carbonate	79.06
Magnesia carbonate	6.65
	101.37

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[1] Darton, N. H. Geology of Albany county. (*see* 18th an. rep't N. Y. state geol. p. 428)

While the stone at South Bethlehem is used chiefly for road material, it could also be used in the manufacture of lime, or Portland cement, for it does not contain an excess of silica. Lying as the material does in close proximity to the clay deposits under the Quaternary terrace, it could be well utilized for cement manufacture.

Curiously enough, however, the limestones of Albany county are but little employed. A partial reason for this may be the great hight and steepness of the escarpment which they form, such conditions interfering somewhat with economic quarrying. There are several quarries at Ravena and one at Aquetuck.

Cayuga county

Extending as it does in a north and south direction, Cayuga county includes several limestone-bearing formations, viz the Upper Helderberg, Lower Helderberg, Niagara, and Clinton.

The Upper Helderberg limestone extends across the county in a northeasterly direction from Union Springs to Auburn, and thence eastward. It is divisible into three members, viz the Onondaga, the Corniferous and the Seneca limestones. The Onondaga is some times spoken of as the gray Onondaga stone, and the last member as the Seneca bluestone.

At Union Springs there are three quarries, all of them in the Seneca bluestone, operated by J. Shalebo, B. P. Smith and G. P. Wood. The stone is used chiefly for building purposes, but some of it runs quite high in carbonate of lime. The following[1] represents the average composition of the largest quarry which is east of the town, and about one mile from the lake. In the quarries on the southern edge of the town, the stone is rather free from impurities in the lower layers, but the upper ones often show a transition to the Marcellus, and in one or two sections a layer of the Goniatite limestone is observable. Plate 29 shows the Corniferous limestone quarry at Union Springs.

At Auburn both the Corniferous and the Onondaga members are quarried. The latter is exposed in some of the smaller quar-

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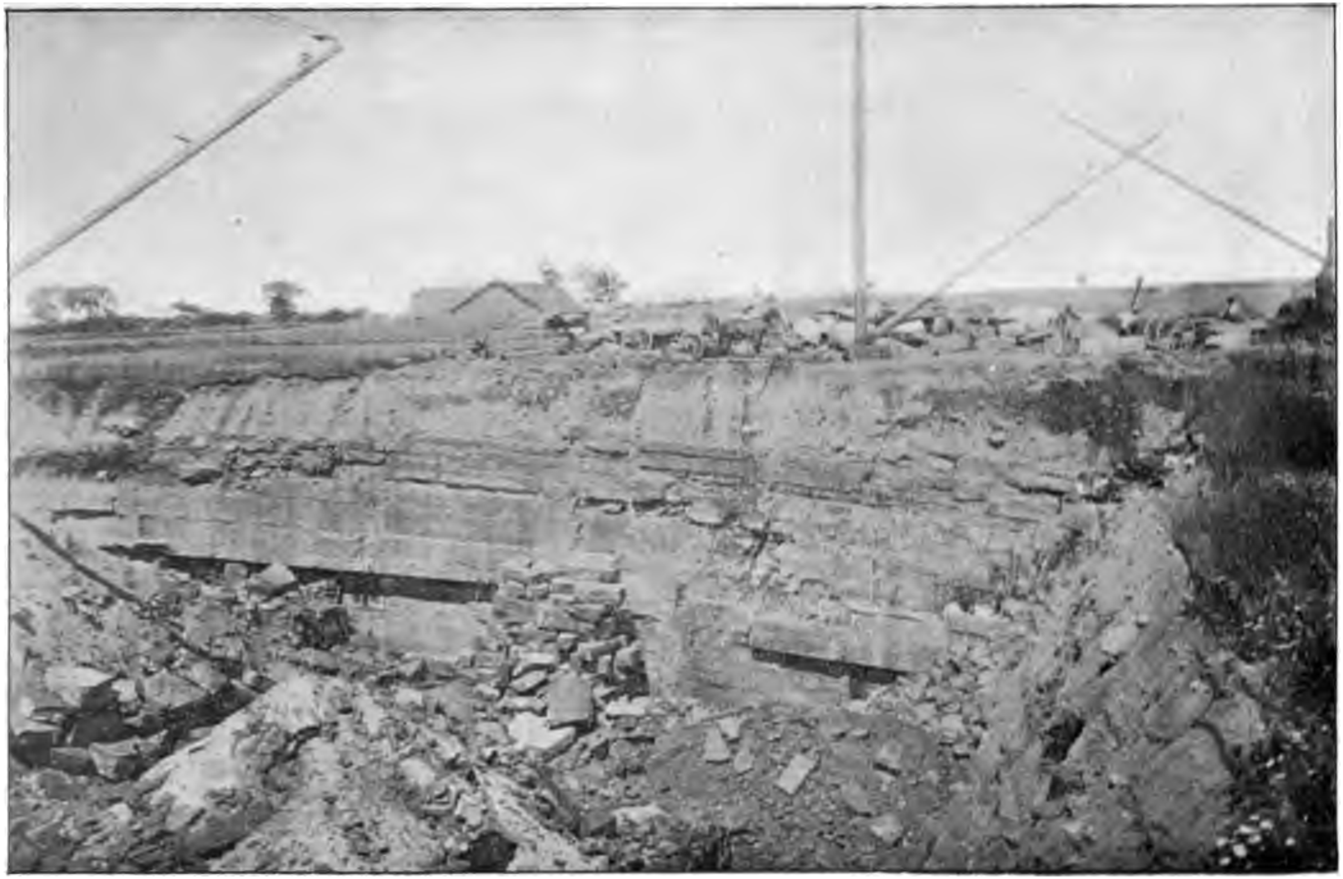
[1] This analysis does not occur in the manuscript. Ed.

Plate 29

To face p. 772



H. Ries, photo.

Quarries in Corniferous limestone at Union Springs

Plate 30

To face p. 773

H. Ries, photo.

General view Montezuma marshes

ries, and the layers are often highly loaded with chert, but in the large quarries of L. S. Goodrich & Son on Cottage street the gray Onondaga member is quarried. The layers here are free from chert, but the stone is a hard, dense fine grained rock, which is used for building and also lime-making. It burns to a lumpy but not very white lime, that of the best quality coming from two layers each about 5 feet thick in the upper portion of the quarry.

The following analysis represents the run of the quarry

Silica	13.5
Alumina	3.7
Ferric oxid	1.5
Lime carbonate	61.66
Magnesium carbonate	19.44
Insoluble	17.5
Total	99.8

The Lower Helderberg limestone also crosses the county in a belt parallel to the Upper Helderberg. It is first exposed at Union Springs on the hill about one and a half miles to the north of the town, on the Lowery farm, where it underlies the Oriskany sandstone. At this point the layers are very shaly, and the purer ones would have to be sought farther toward the northern edge of the outcropping beds of the formation. The width of the belt is from two to three miles. So far as the writer is aware, it is not quarried within the limits of the county. This may be partly due to the fact that there is a heavy covering of drift in many places that would easily tend to cover it up.

At Montezuma the works of the Duryea Portland cement co. were built to use the marl underlying Montezuma swamps, but, since their destruction by fire several years ago, no attempts have been made to revive the industry at that point. The Montezuma marshes (pl. 30), underlie an extensive tract, and marl is said to occur under them at several points. Borings were made by the writer across the swamp at a point two miles north of Union Springs but no marl was found.

Chautauqua county[1]

The only lime deposits are a few scattered beds of marl. The most important is on Cassadaga lake, and a Portland cement plant was erected at this point several years ago, but is now closed down.

Clinton county[2]

Calciferous. Rocks of this age are abundantly exposed in Champlain, Beekmantown and Peru townships. The rocks are usually blue gray, massive, sandy dolomites. Owing to their sandiness they have little value for the manufacture of lime or cement.

The Trenton and Chazy limestones occupy a broad belt which extends along the western side of Lake Champlain from Peru northward to the Canadian boundary, the western edge passing close to West Chazy, Chazy and Coopersville.

Chazy limestone. This limestone is well exposed at the village of Chazy as well as in other parts of Chazy township, specially just north of Plattsburg, and on Bluff point two miles south of the latter place, whence it extends south into Peru, where the lower portion of the formation is well shown. The aggregate thickness of the Chazy limestone at Chazy village is 740 feet, while at Valcour it is said to be 890 feet. The rock is quarried at a number of points for obtaining marble, rough building stone or stone for lime.

Black river limestone. The rocks of this group occur as massive dark colored beds, but are well exposed at numerous points in

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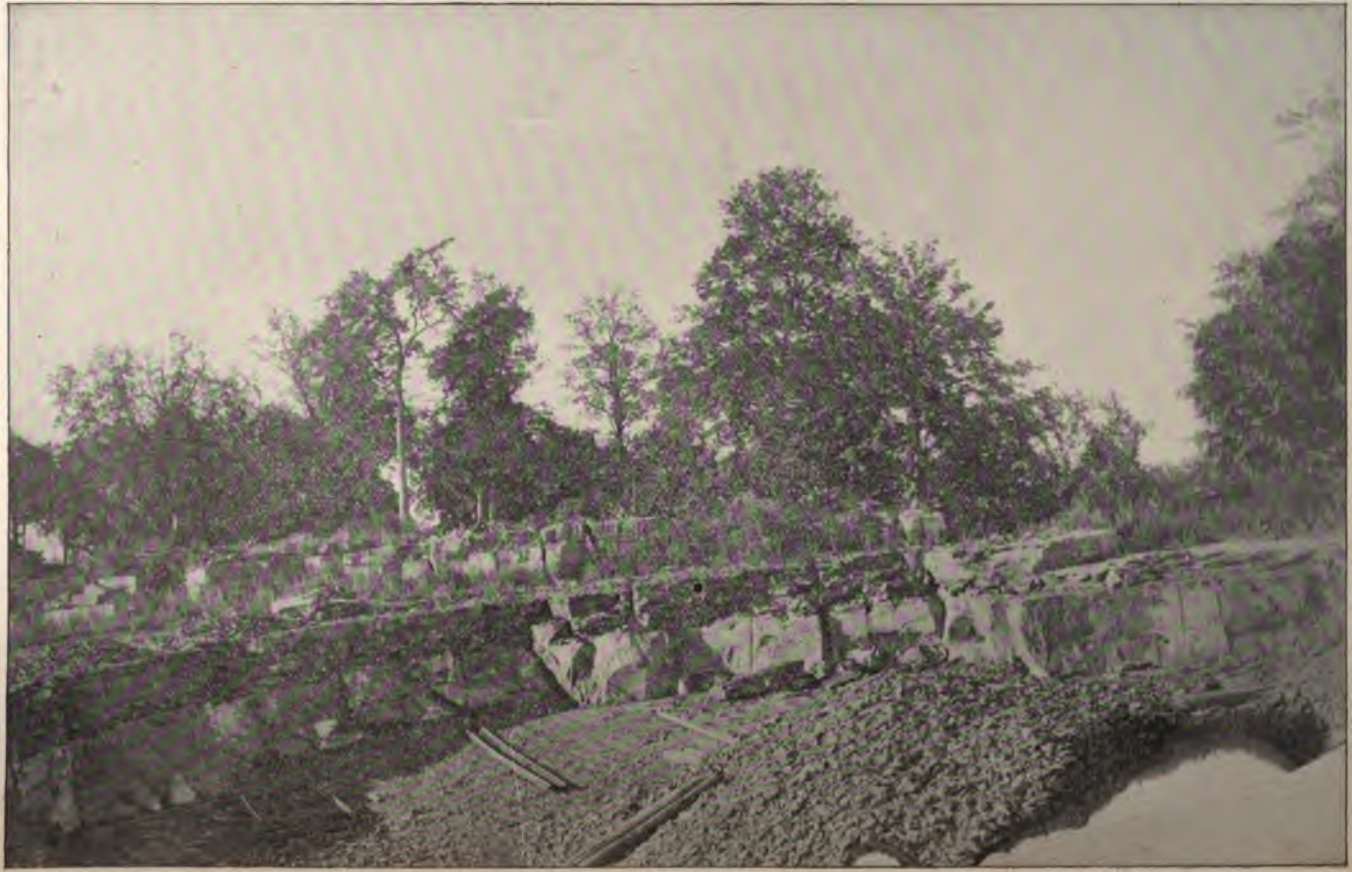
[1] Hall, James. (*see* Geol. 4th dist. N. Y. p. 493)

[2] Cushing, H. P. Geology of Clinton county. (*see* 13th an. rep't N. Y. state geol. p. 513)

——— Faults of Chazy township, Clinton co. (*see* Bul. geol. soc. Am. 6: 285)

——— Geology of Rand Hill and vicinity, Clinton county. (*see* 19th an. rep't N. Y. state geol. p. 39)

Emmons, Ebenezer. Geol. 2d dist. N. Y. 1842.



H. Ries, photo.

Lime quarry at Chazy

Chazy overlying the Chazy limestone, but outside of the village and in Chazy township it is not very well exposed. According to Cushing it has a thickness of 30 to 50 feet and is a brittle black limestone with a conchoidal fracture.

Trenton limestone. This is also well exposed in the town of Chazy and in addition in the town of Plattsburg. Cushing states that in the bed of the river just east of the Chazy village 150 feet is exposed lying on the Black river limestone, while on Crab island about 200 feet of it can be seen. The lower portion of the Trenton limestone generally exhibits beds of a slaty character and is probably of insufficient purity for any chemical use except that of making common lime and for fertilizing purposes or perhaps Portland cement. Also in northeastern Plattsburg township, and extending into southeastern Beekmantown, the rocks according to Cushing form a series of black slaty limestones which are excellently exposed on Cumberland head.[1]

The Chazy limestone is of high purity and makes a most excellent quality of lime.

The following is an analysis made by D. H. Newland.

Silica	.72
Alumina and ferric oxid	.39
Lime carbonate	96.24
Magnesium carbonate	3.02
	100.37

The quarries are near the railroad and the product can be easily shipped.

There are several lime quarries in operation in the village of Chazy, the one being on the eastern edge of the town and another about a mile out (pl. 31). Recently a third quarry has been opened on the southeastern edge of the village, and three limekilns erected. It affords an excellent location for cement manufacture, as the lowlands which the limestone ledges border are underlain by clay. The Chazy limestone bears a high reputation not only for the manufacture of lime, but also as a furnace flux.

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[1] Cushing, H. P. Geology of Clinton county. (*see* 18th an. rep't N. Y. state geol. p. 518)

The following is an analysis of the burned stone used for flux at Troy, E. Touceda, analyst.

Lime oxid	97.48
Magnesium oxid	1.4
Alumina	.14
Ferric oxid	.12
Silica	.79
Total	99.53

Columbia county[1]

The limestones in the eastern part of the county are of little importance on account of their impure nature, but on Becraft mountain east of Hudson the stone has been extensively quarried for a number of years to supply the furnaces at Troy with flux. Two types of stone are found here, viz the Becraft or Scutella limestone, and the blue Pentamerus rock.

The Pentamerus limestone is quarried on the cemetery property at the northeastern edge of the town (pl. 32). It is well exposed in a face about 100 feet long and 25 feet high. With the exception of the upper 6 feet the layers are quite free from chert. The rock shows occasional cavities with calcite crystals and at times quartz, but otherwise probably does not run over 3% or 4% in silica. While the stone has hitherto been used only for road material, still it affords a source of limestone for the manufacture of Portland cement, the necessary clay being obtainable from the terraces north of the city.

The most abundant material is the Becraft limestone already referred to. Extending along the top of the ridge are a series of

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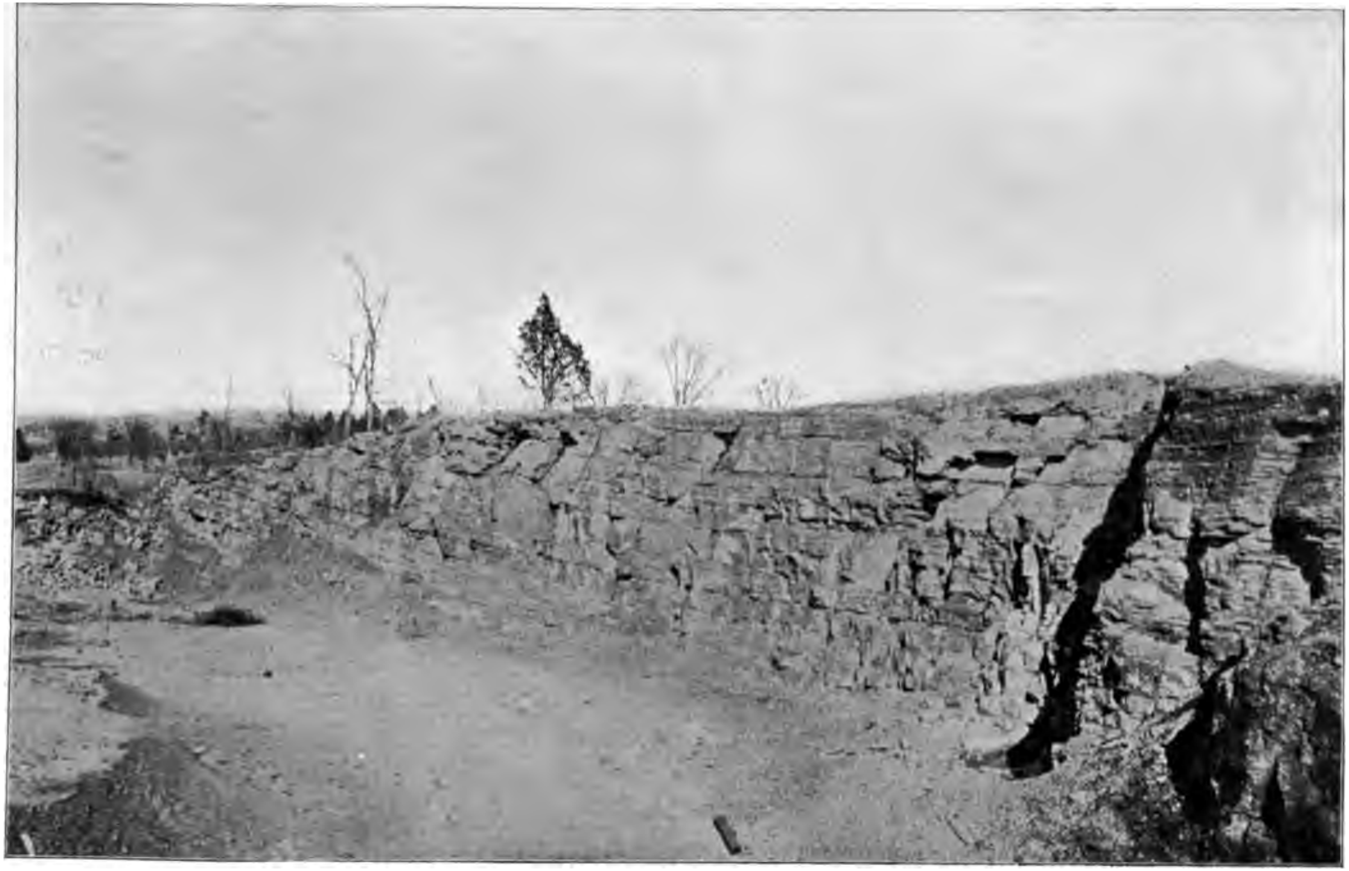
[1] Bishop, I. P. On certain fossiliferous limestones of Columbia county N. Y. and their relations to the Hudson river shales and the Taconic system. (*see* Am. jour. sci. 1886. '32: 438).

Mather, W. W. Geol. 1st dist. N. Y. 1843.

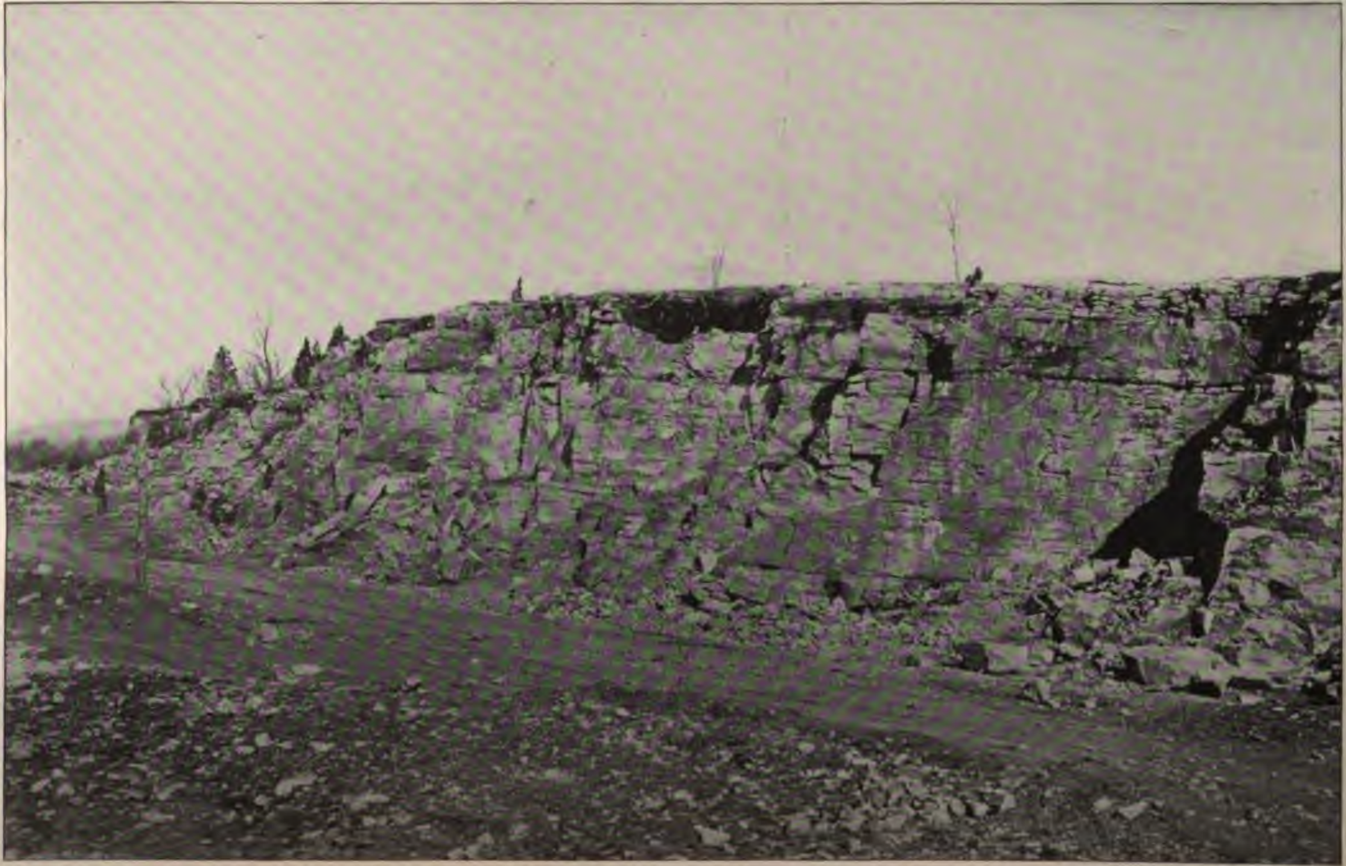
Plate 32



H. Ries, photo.

Quarry in Pentamerus limestone, Hudson, Columbia co.

Plate 33



H. Ries, photo.

Shute & Rightmyer's quarry in Becraft limestone near Hudson openings, which were originally opened as marble quarries, but found unsuitable and subsequently worked for dimension stone and flux, these operations continuing to the present.

The limestone is a coarsely crystalline, fossiliferous rock, of moderately pure and quite uniform character. The stone has to be hauled 600 to 1000 feet to the railroad siding, thus permitting easy shipment.

The following analyses, no. 1 by T. Egleston and no. 2 by the chemist of the Burden iron works at Troy illustrate the character of the stone.

	1	2
Lime	51.4	......
Lime carbonate	......	91.7..
Carbon dioxid	41.191	......
Magnesium carbonate	......	3.51
Magnesia	2.233	......
Alumina	.635	1.01
Ferric oxid	1.819	.55
Silica	1.842	1.89
Sulfur dioxid	.145	.049
Phosphorus	.149	.022
Water	.271	......
	99.685	98.731

While Mr Jones still owns some of the quarries, the majority are said to be owned by Shute & Rightmyer (pl. 33).

Dutchess county[1]

The limestones in the eastern part of the county are a continuation of those found in Westchester county and follow the line of the Harlem river railroad, while those found in the central and western portions of the county are a continuation of the Orange county Cambro-Silurian limestone belts. The former are metamorphosed limestones and partake of the nature of marble, being highly crystalline, while the latter are not.

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[1] Dwight, W. B. On the recent explorations in the Wappinger valley limestones of Dutchess co., N. Y. (*see* Am. jour. sci. 1879. 17: 390)
—— Recent investigations and palaeontological discoveries in the Wappinger limestone of Dutchess and neighboring counties, New York state. (*see* Proc. Am. ass'n adv. sci. 31: 384; *also* Am jour. sci. 1884. 27: 249)
Mather, W. W. Geol. 1st dist. N. Y. 1843.

The eastern belt. While there are outcrops of the limestone at a number of points in the valley followed by the Harlem railroad, only two large openings have been made. These are at Dover Plains and South Dover.

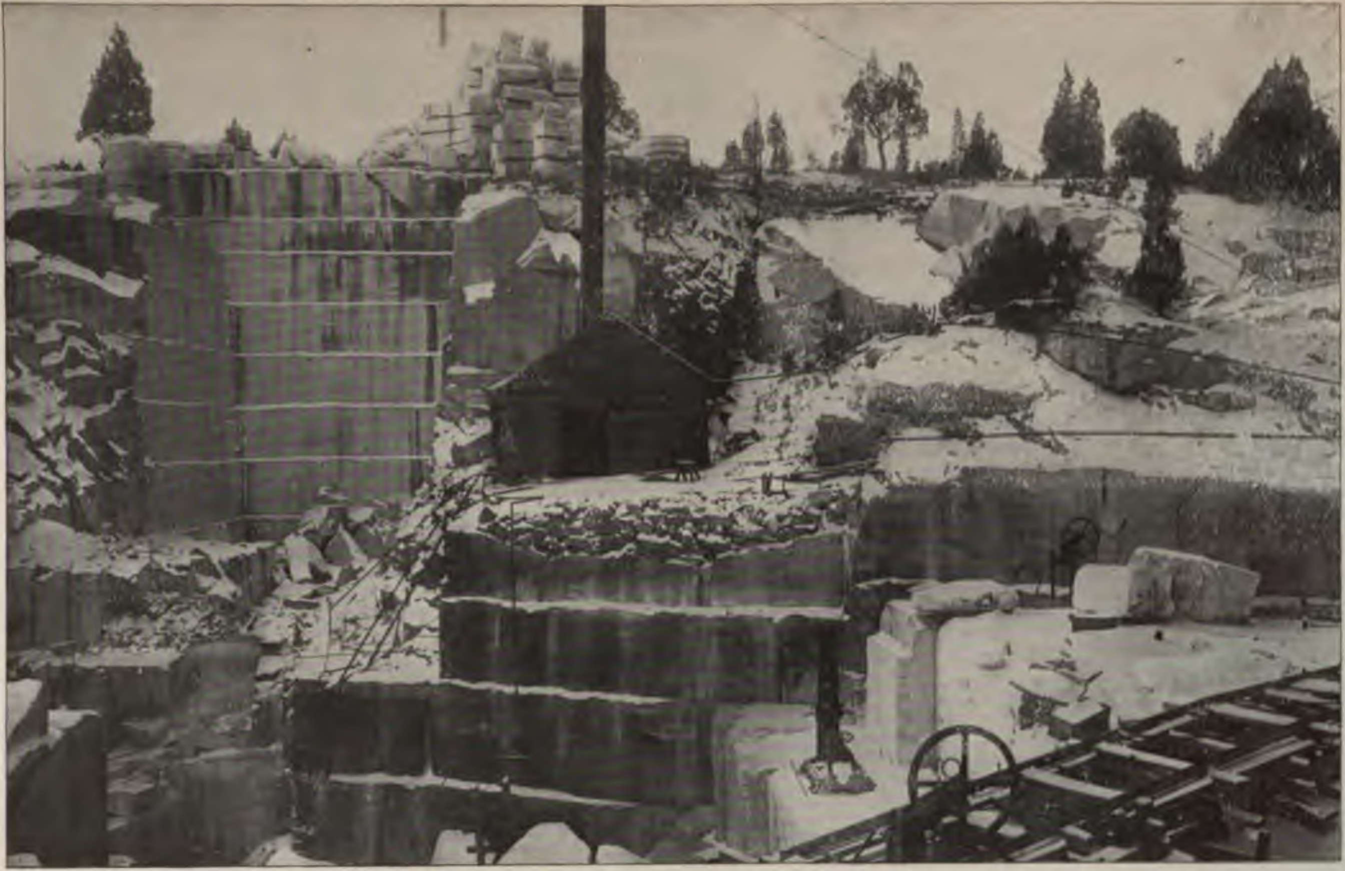
At Dover Plains, G. & J. H. Ketcham have operated a quarry along the highroad one half mile southeast of the town. The rock is a soft, fine grained dolomite of gray or white color. The opening is about 200 feet long, 20 to 30 feet wide and 10 feet deep. No analysis was made of the stone but several samples were examined to determine their insoluble matter, which ran from 2 to 3%.

The South Dover marble co. has a large quarry (pl. 34) on the hill 2½ miles northeast of the station. The rock is a fine grained, white dolomite and has hitherto been used only for structural purposes. It has to be hauled to the railway. In appearance it is very free from impurities. The following analysis of the rock was furnished by the superintendent of the company.

Silica	.7
Ferric oxid	.25
Alumina	.37
Lime	30.63
Magnesia	20.25
Soda	.12
Potash	.46

The stone is brought down to the railroad over a private trolley line.

The limestones in the western part of the county are usually a hard, fine grained bluish gray rock, containing less magnesia than the whiter phases to the southeast and east. It has been used for lime but on the whole is so silicious that the resulting lime would be lean.

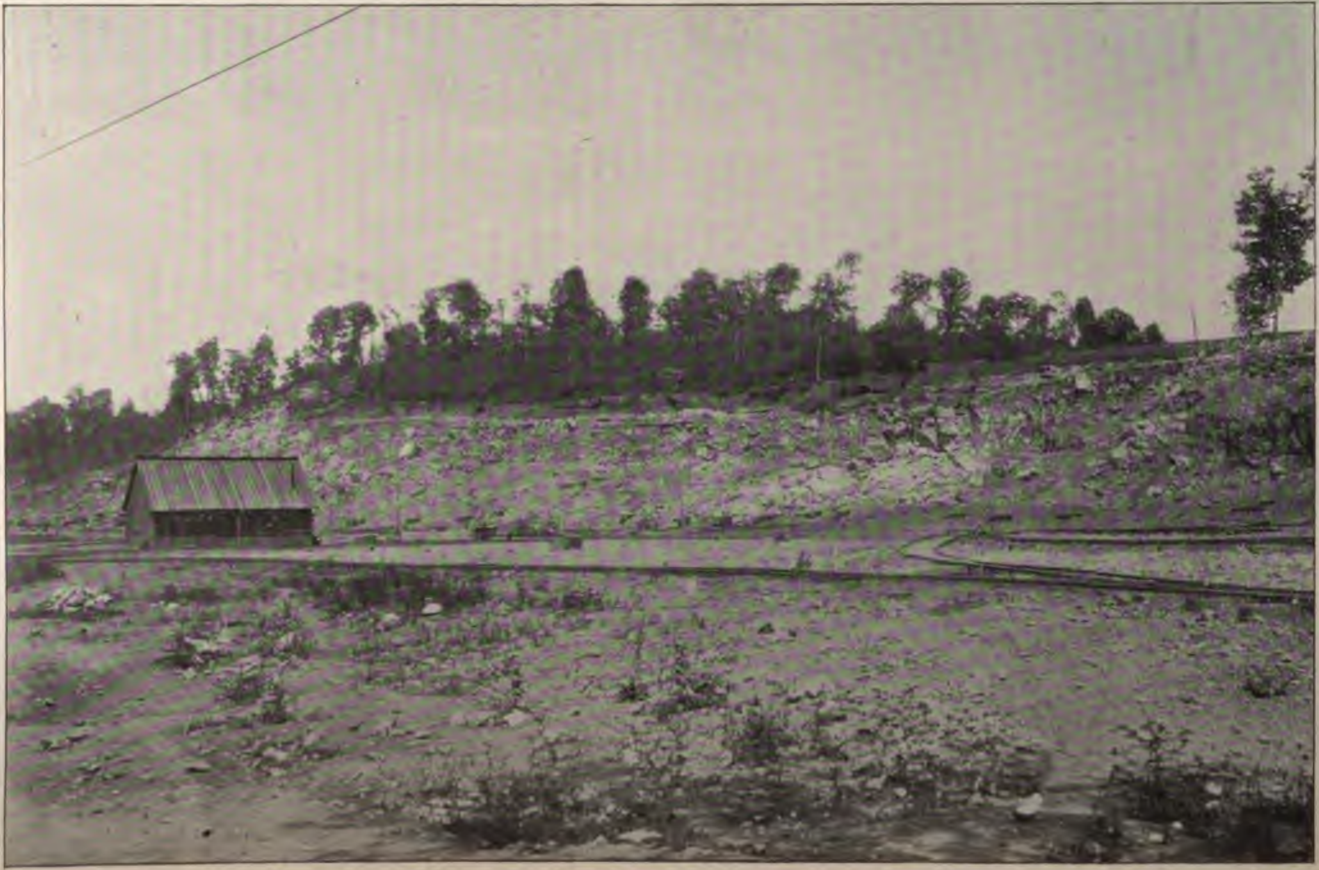


H. Ries, photo.

Quarry of South Dover marble co. South Dover

Plate 35

To face p. 779



H. Ries, photo.

Quarries at Clinton Point, north of New Hamburg

Since dolomitic limestones tend rather to disintegrate than to decompose, their outcrops are often surrounded by a white granular sand, and are easily discernible for some distance. The western belt has been quarried in large quantities at Clinton point (pl. 35), 2 miles north of New Hamburg. Its silicious nature restricts its use to road metal.

An analysis of this stone gave:

Lime	29.07
Magnesia	16.29
Carbonic acid	40.76
Alumina	2.33
Ferric oxid	.47
Silica	10.17
	99.09

Erie county[1]

The only limestone formations represented in this county are the hydraulic or waterlime, the Onondaga and the Corniferous.

According to Bishop, "the northern edge of the Corniferous limestone, together with the Onondaga limestone and the upper part of the hydraulic limestone, forms a well defined escarpment, which runs in a general southwest direction on the Genesee county line to Buffalo. Most of this distance the escarpment is nearly parallel to the Bloomingdale and Williamsville road. The hydraulic limestone is generally visible at the base of the escarpment, where it forms a layer of variable thickness in the face of the cliff. Sometimes it forms a terrace from a few feet to 200 yards in width which runs parallel to the escarpment. This is specially well marked between the Williamsville and Buffalo city line. The Onondaga limestone in Erie county forms a thin band between the hydraulic limestone and the overlying Corniferous limestone. It varies in color from blue gray to a light gray, and also varies in thickness, reaching its maximum of 35 feet in Fogelsonger's quarry at Williamsville. It is the same thickness 2 miles farther on but then begins to thin out rapidly. The formation in Erie county, instead of being of one continuous bed, is really a series of lenticular masses occurring at the same horizon. The Corniferous limestone in Erie county forms somewhat of an escarpment, as already mentioned. The rock outcrops are not as a rule very extensive, but good ones occur a few miles below Millgrove near a dam across Endicott creek, and again in the bed of the same stream for 3 miles below Wilhelm, and also near the same place. Again this limestone is found in Gage creek at Kieffer's quarry near the transit road about a mile west of Lancaster.

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[1] † Bishop, I. P. Structural and economic geology of Erie county. (*see* 15th an. rep't N. Y. state geol. p. 305)

Hall, James. Geol. 4th dist. N. Y. p. 469.

Pohlman, J. Cement rock and gypsum deposits in Buffalo. (*see* Trans. Am. inst. min. eng. Oct. 1888)

Hydraulic limestone. This extends through Williamsville, Clarence and Akron. Along the whole line of its outcrop it has been quarried at numerous places but generally only for building purposes. The section at the works of the Buffalo cement co. gives the following relations of the three limestones: flint and limestone, Corniferous, 3 to 9 feet; Onondaga lime, 5 feet 8 inches; loose friable limestone, 6 inches; gypsum crystal, 6 inches; hydraulic limestone, porous, known as bullhead, 7 feet; cement rock used for burning, 3 feet 8 inches; impure hydraulic lime at bottom (pl. 36).

The bullhead stratum furnishes the greater part of the waterlime used for building purposes.

Onondaga limestone. One or two of the lenticular masses already mentioned occur near Williamsville in the quarry of Fogelsonger & Young. It is highly fossiliferous and quite pure, as shown by the following analysis made by H. Carlson and quoted by Bishop.[1]

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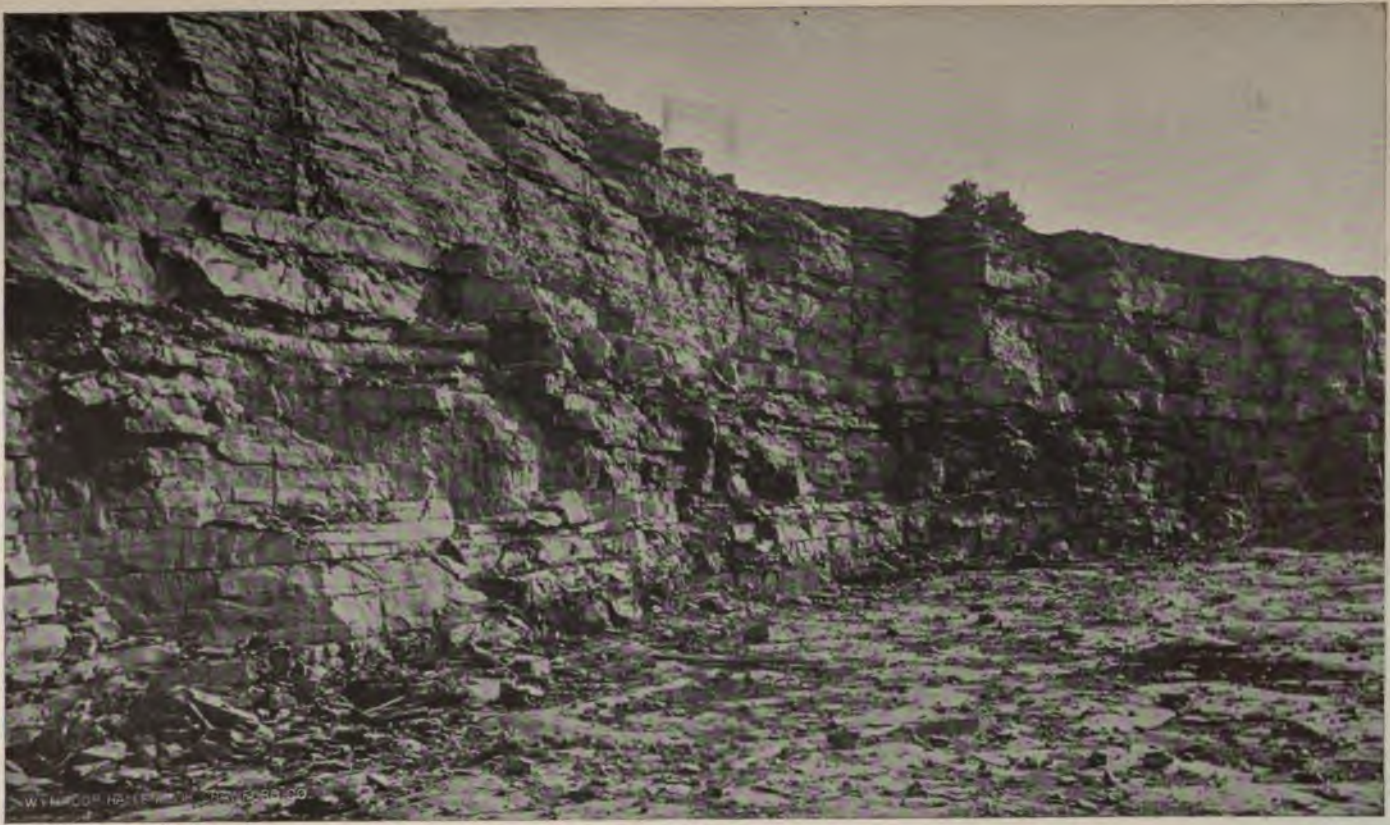
[1] Geology of Erie county. (*see* 15th an. rep't N. Y. state geol. p. 331)

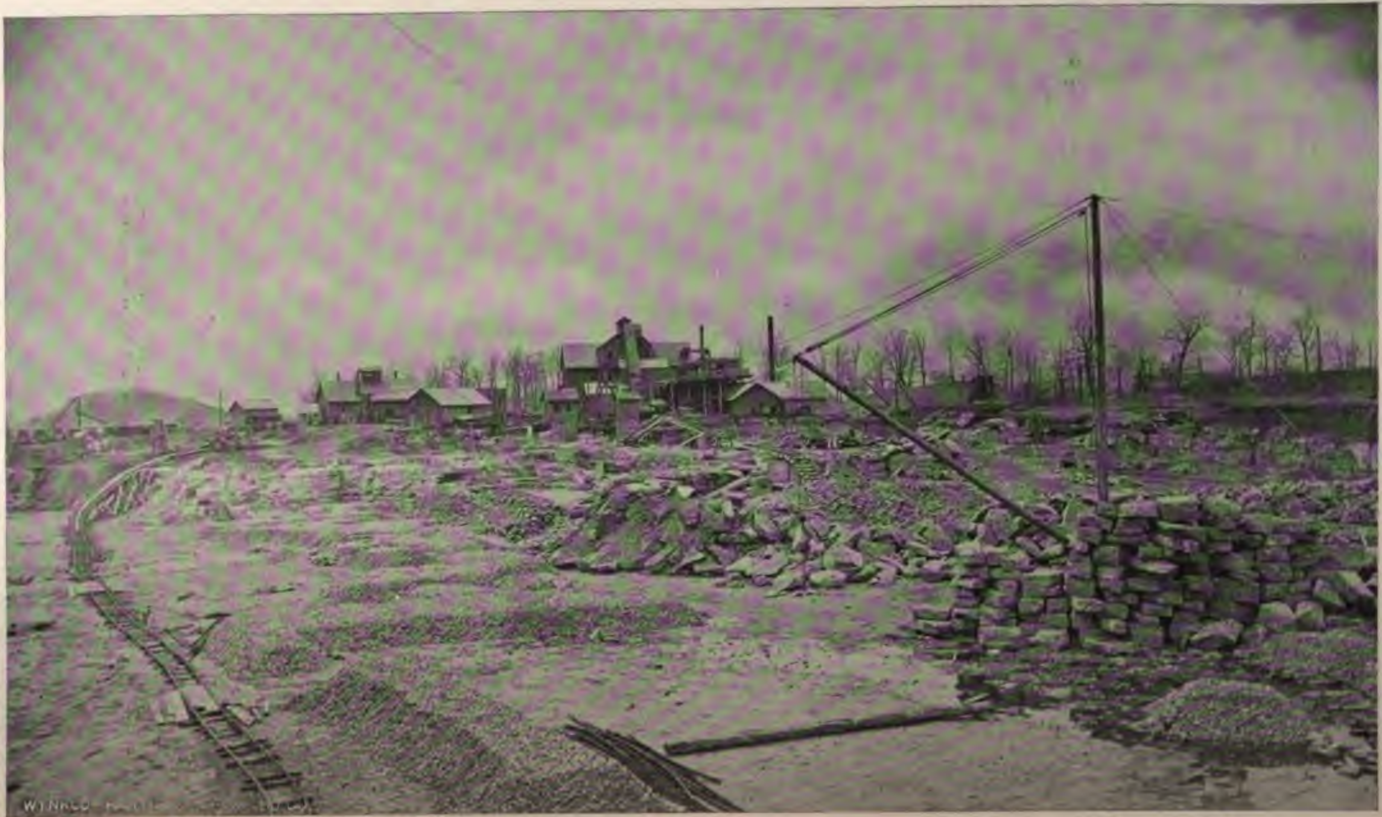


I. P. Bishop, photo.

Quarry of the Buffalo cement co., Buffalo, Erie co.

Plate 37

To face p. 781



I. P. Bishop, photo.

Road metal and paving block quarry of the Barber asphalt co. Near Humboldt parkway, Buffalo, Erie co. Corniferous limestone

Lime carbonate	96.54
Magnesium carbonate	1
Iron and alumina oxid	.84
Silica	1.17
Sulfur	.101
Phosphorus	.017
	98.668

Some of the rock is used for smelting purposes, and the waste is burned for lime.

Corniferous limestone. The chief use for this is also for building operations. The largest quarry in Erie county is that of the Buffalo cement works, but there are numerous other smaller ones. The limestone, while making a good building material on account of its hardness, is very cherty in places, and therefore for any chemical or similar work would probably have to be hand picked. The limestone is usually thickly bedded (pl. 37).

Essex county[1]

The pre-Cambrian rocks of Essex county often include a series of crystalline limestones, which are not infrequently speckled with grains of pyroxene and other dark silicates. Occasionally these silicates are segregated into bunches, thus leaving the rest of the rock comparatively free from impurities. At times the limestone beds attain a thickness of 50 feet to 100 feet, as at Port Henry, where they have been quarried for flux. The quarry has not been operated for several years.

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[1] **White, T. G.** Geology of Essex and Willsboro townships, Essex co., N. Y. (*see* **Trans. N. Y. acad. sci. 13: 214**)

Merrill, G. P. On serpentinous rocks from Essex county. (*see* Proc. U. S. **nat. mus. 12: 595**)

Brainard, E. The Chazy formation in the Champlain valley. (*see* Bul. 2. **Geol. soc. Am. p. 293**)

——— **& Seely, H. M.** The Calciferous formation in the Champlain valley. (*see* **Bul. 3. Am.** mus. nat. hist. p. 1; also Bul. 1. Geol. soc. Am. p. 50)

Kemp, J. F. Preliminary report on geology of Essex county. (*see* 13th **an. rep't N. Y. state** geol. p. 625)

——— Geol. of Moriah and Westport townships, **Essex co., N. Y.** (*see* **Bul. 14. N. Y. state** mus.)

Emmons. Ebenezer. Geol. 2d dist. 1842.

Three distinct areas of Chazy and Trenton limestones occur in this county. The first forms Willsboro point and extends southward as far as Whallonsburg. A second area begins at Westport and extends southward to the town of that name. A third is on Larrabees point.

The Black river limestone member of the Trenton is usually heavy bedded, very tough and compact. The rock has been quarried on Crown point.

The Trenton proper, also exposed on Crown point, is 150 feet thick, but is usually thin bedded, showing alternations of limestone and shale layers. The Trenton has been used at several places for making lime, but no definite statement can be made concerning the purity of any given beds, as they are variable. At times the rock is quite low in silica. Large quarries have been opened on Willsboro point (pl. 38), and in the town of Essex, and the stone from the former was shipped to New York city.

A partial analysis of the Chazy limestone on Willsboro point, furnished the writer by Prof. J. F. Kemp, showed:

Lime	51
Magnesia	1
Silica	2.43

The following represent the average composition of 1) the upper 10 feet and 2) the lower 10 feet of the quarry from analyses made of samples collected by the writer.

	1	2
Silica	4.4	4.6
Alumina	7.1	4.1
Ferric oxid	3.5	1.9
Lime carbonate	79.2	87.7
Magnesium carbonate	4.2	.98
Insoluble	15	12.6
Water	....	2

The following additional ones are given by T. G. White.[1]

1 Lower beds of quarry on Willsboro point.

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[1] † Geology of Essex and Willsboro townships, Essex co., N. Y. (*see* Trans. N. Y. acad. sci. 13: 214–31)

[illegible]

2 Same as 1 with carbonates calculated.

3 An analysis of Chazy limestone quoted from Boynton,[1] and said to be from Willsboro.

	1	2	3
SiO_2	2.43	2.43	21.39
CaO	51	.....	.....
$CaCO_3$	....	91.1	70.31
Al_2O_3, Fe_2O_3	.41	.41	3.61
MgO	1	2.1	1.09
Na_2O	....	.....	tr.
K_2O	....	.....	.8
Cl	....	.....	.31
H_2SO_4	....	.....	.69
H_3PO_4	....	.....	.2
Organic matter	....	.....	1.4
	54.84	96.04	99.8

Fulton county[2]

The Calciferous and Trenton limestones form a crescent shaped belt extending from Crum creek, northwest of St Johnsville, through Garoga, Johnstown, Gloversville and Mayfield up to Northville. A second belt extends from Northville to the southern boundary and has a width of about 6 miles.

Quarries are in operation at Cranberry creek and Mayfield.

Genesee county[3]

A very small triangular area of Niagara limestone occurs in the northeastern corner of the county and a second very thin strip along the northern edge.

The Helderberg, on the contrary, extends through the central part of Genesee county, passing through Batavia, Stafford, East

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[1] Trans. N. Y. state agric. soc. 1852. 12: 801.

[2] Darton, N. H. Geology of the Mohawk valley in Herkimer, Fulton, Montgomery and Saratoga counties. (*see* 47th an. rep't N. Y. state mus. p. 601)

—— Preliminary description of the faulted region of Herkimer, Fulton, Montgomery and Saratoga counties. (*see* 14th an. rep't N. Y. state geol. p. 33)

Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.

[3] Hall, James. (*see* Geol. 4th dist. N. Y. p. 464)

Pembroke and Corfu, and Leroy. A quarry is operated by J. Merrill near Batavia, but the greater number of quarries lie in the Corniferous at Leroy, where much stone is extracted. The Leroy rock is dark colored, medium to fine grained and is used both for lime and furnace flux. The principal quarry at Leroy is that of Morris & Strobel, but most of the quarries are at Lime Rock near Leroy. The quarries are mostly small, and many of the layers cherty, but those free from chert (and they are at times as much as 3 feet thick) are of very good quality. The following analysis of Leroy limestone from Howells quarry was kindly furnished by the Tonawanda Iron & Steel co.

Lime carbonate	92.46
Magnesia carbonate	1.86
Silica	5
Alumina	.6
	99.92

A second analysis made of a sample collected by the writer from Morris & Strobel's quarry yielded:

Silica	5.96
Alumina	3.16
Ferric oxid	1.34
Lime	49.07
Magnesia	1.44
Carbon dioxid	40.13
	101.1

The third analysis shows composition of lime, furnished by W. S. Brown at Leroy.

Lime	94
Magnesia	1.4
Iron oxid	1.1
Silica	3.2
Alumina	.3
	100

Overlying the gypsum beds which occur in the town of Leroy there is occasionally found a drab limestone resembling cement rock in appearance. The following analysis was made of a sample from the land of Mr Howell near Leroy, D. H. Newland, analyst.

Silica	4.02
Alumina	1.48
Ferric oxid	1.07
Lime carbonate	57.87
Magnesium carbonate	35.09
	99 53

This composition would not indicate that the material had very great hydraulic properties, as it runs low in clay.

According to Hall[1] the hydraulic limestone is exposed on Allens creek, 2 miles north of Leroy, and also at Morganville.

Genesee county contains several swamps underlain by marl.

One extensive deposit occurs along the line of the New York Central railroad about a mile west of Bergen, on the land of P. Snyder, and G. E. Parish and also on what is known as the Doran farm. Attempts have been made to organize a Portland cement company to work the material. The following analysis made by J. A. Miller, of Niagara university, was furnished.

Silica	.49
Alumina and ferric oxid	.35
Lime sulfate	3.48
Lime carbonate	94.12
Magnesia	tr.
Undetermined	1.56
	100

Marl is also said to underlie the Beaver Meadows at Leroy.

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[1] Geol. 4th dist. N. Y. 1843. p. 405.

Greene county[1]

The only limestone formations in the county are those of the Lower Helderberg and Upper Helderberg, which extend across the eastern part of the county from its northern to its southern border, the two belts being separated by the Oriskany sandstone.

The Onondaga is usually represented by its cherty member, the Corniferous, and is of little use except for building purposes and road material, but the Lower Helderberg supplies an abundance of lime rock, which could be employed in several directions. At the northern boundary the Lower Helderberg limestone ridge is probably 2 miles back from the river, the shore lines of the Quaternary terrace abutting against it. In this vicinity it is quarried near New Baltimore, by W. Fuller's Sons. At Catskill, however, the ridge approaches close to the Hudson, and is easily available for shipment. Both the Scutella and also the underlying members are exposed in the ridge, which closely follows the river from Catskill southward to Saugerties, and, while they have been much used for building, other uses have remained in the background.

Recently the possibility of combining the Helderberg limestone with the nearby Quaternary clays for the manufacture of Portland cement has been recognized, and several factories are in contemplation, while one large works is nearly completed at Smiths Landing.

Where a selection of certain layers is to be observed, the dip of the beds has to be considered, for in this ridge it is quite variable, owing to the folding which the region has been subjected to.

The Becraft limestone forms the most massive member of the Lower Helderberg in Greene county. It is similar in its characters to that found on the eastern side of the river near Hudson, and is underlain by the Tentaculite and Pentamerus. West of Catskill it has been extensively quarried by George Holdredge

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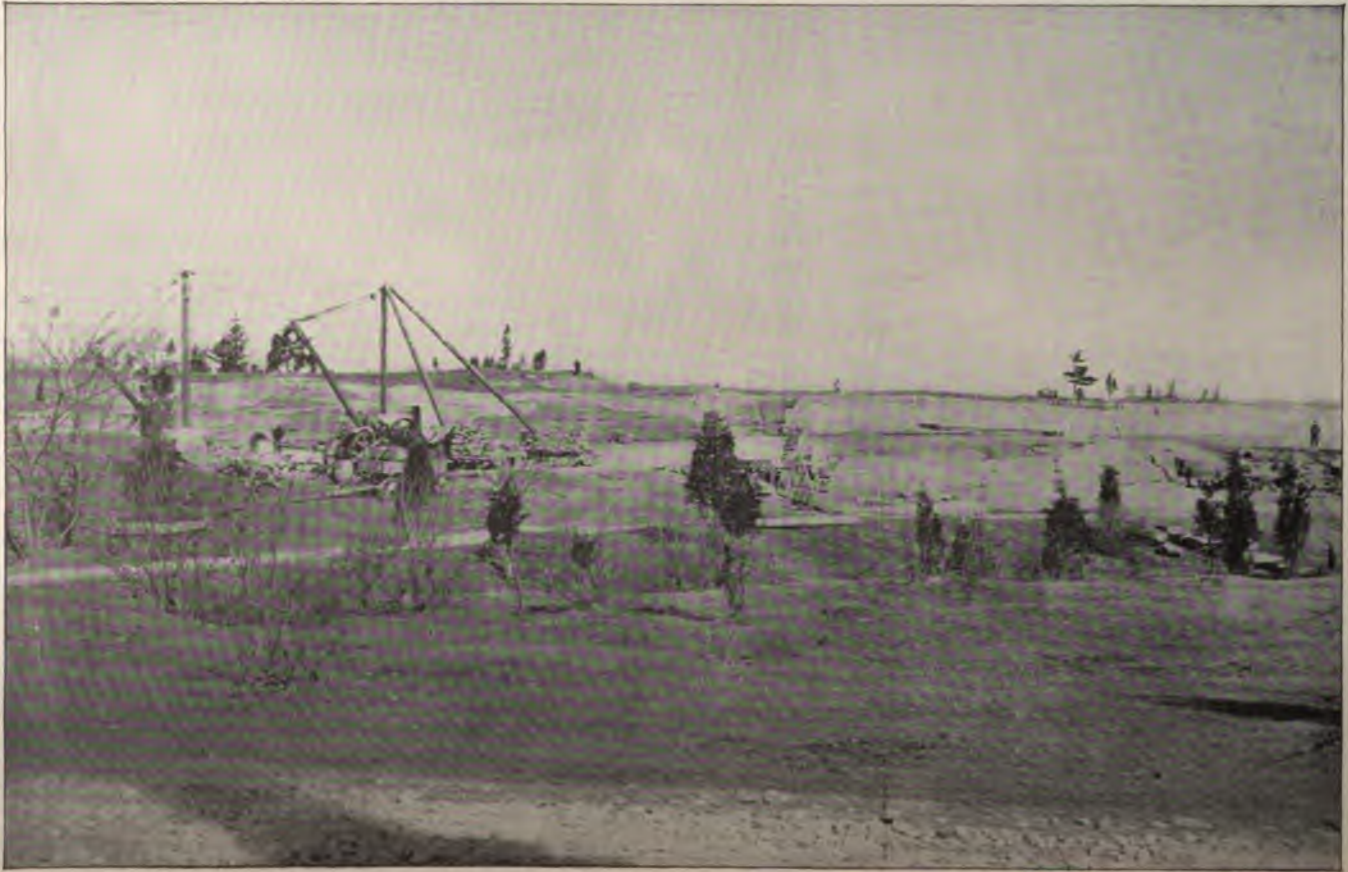
[1] Mather, W. W. Geol. 1st dist. N. Y. 1843.

Plate 39

To face p. 787

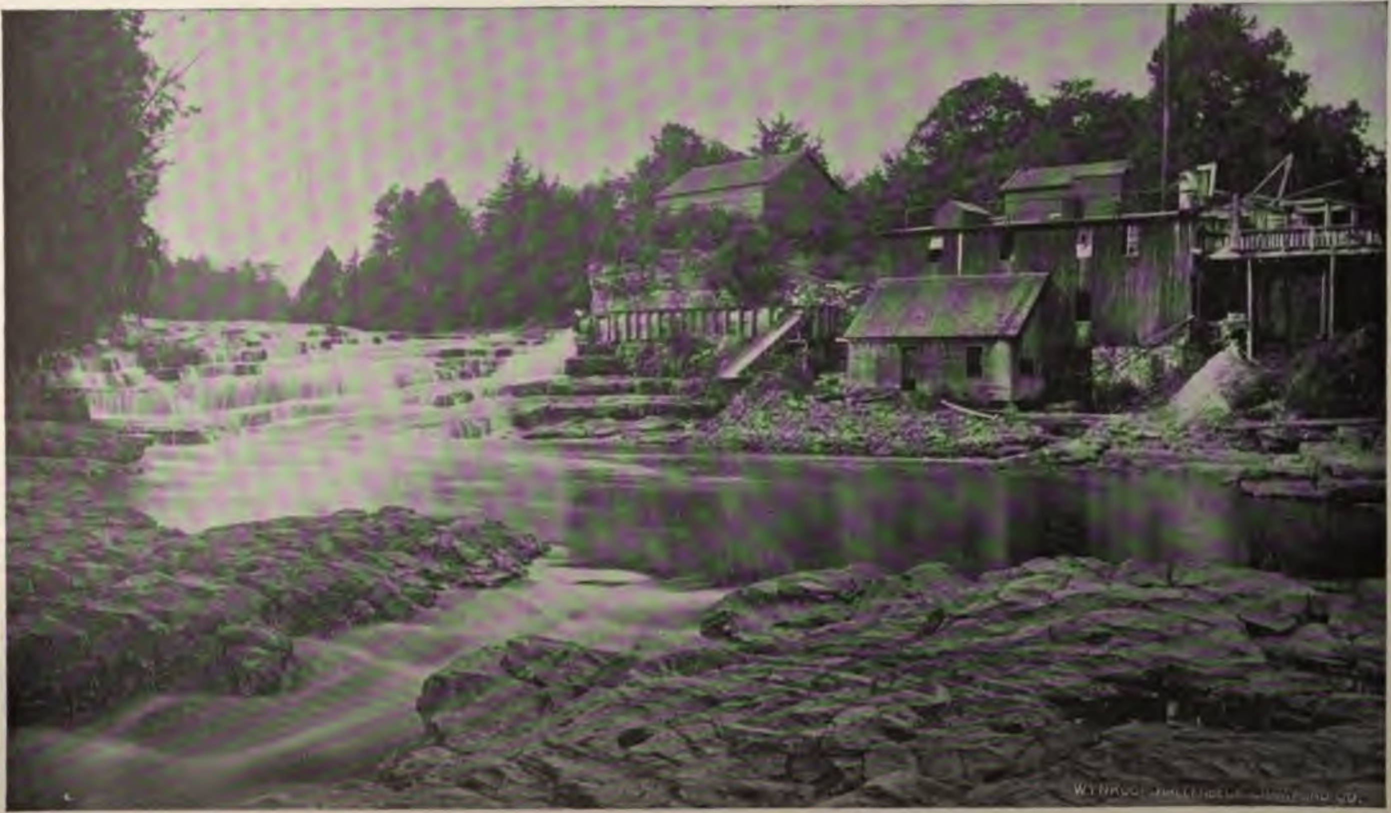


H Ries, photo.

Becraft limestone in G. M. Holdredge's quarry, west of Catskill

Plate 40

To face p. 787



N. H. Darton, photo.

Calciferous sandrock, East Canada creek, Herkimer co. 2 miles above its mouth (pl. 39). The rock shows the usual coarse grained, fossiliferous character, and the beds lie nearly horizontal with a slight dip to the west. The stone is quite homogenous, and a sample analyzed by the writer and representing the average of the quarry gave:

Silica	2.75
Alumina	1.5
Ferric oxid	1.6
Lime	53.1
Carbonic acid	42.1
	101.05

The quarries lie about 1 mile from the river and the West Shore railroad.

Herkimer county[1]

The Calciferous sandrock occurs in the county around Little Falls and is well exposed in several quarries in the town and also on the south side of the river. It is generally a light bluish gray, fine grained, massively bedded sandy limestone whose weathered surfaces are generally dirty buff. The following analysis will illustrate well its silicious and magnesian character.

Silica	10.5
Alumina	3.03
Ferric oxid	.77
Lime carbonate	47.96
Magnesium carbonate	36.89
	99.15

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[1] **Darton, N. H.** Geology of Mohawk valley in Herkimer, Fulton, Montgomery and Saratoga counties. (*see* 47th an. rep't N. Y. state mus. p. 603)
—— Preliminary description of the faulted region of Herkimer, Fulton, Montgomery and Saratoga counties. (*see* 14th an. rep't N. Y. state geol. p. 33)
White, T. G. Report on the relations of the Ordovician and Eo-Silurian rocks, in portions of Herkimer, Oneida and Lewis counties. (*see* 51st an. rep't N. Y. state mus. 1: r21)
Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.

The other limestone formations found in the county are of much greater importance. The Helderberg limestones extend across the southern edge of the county as a belt several miles wide, whose northern limit passes through the towns of Jordanville, Columbia, Cedarville and Cedar Lake. They have been quarried at several places, Columbia among them, for lime burning, but their distance from the railroad is a serious objection.

The Tentaculite limestone is utilized at Columbia south of Little Falls for the manufacture of lime, and a sample from A. Manning's quarry showed the following composition.

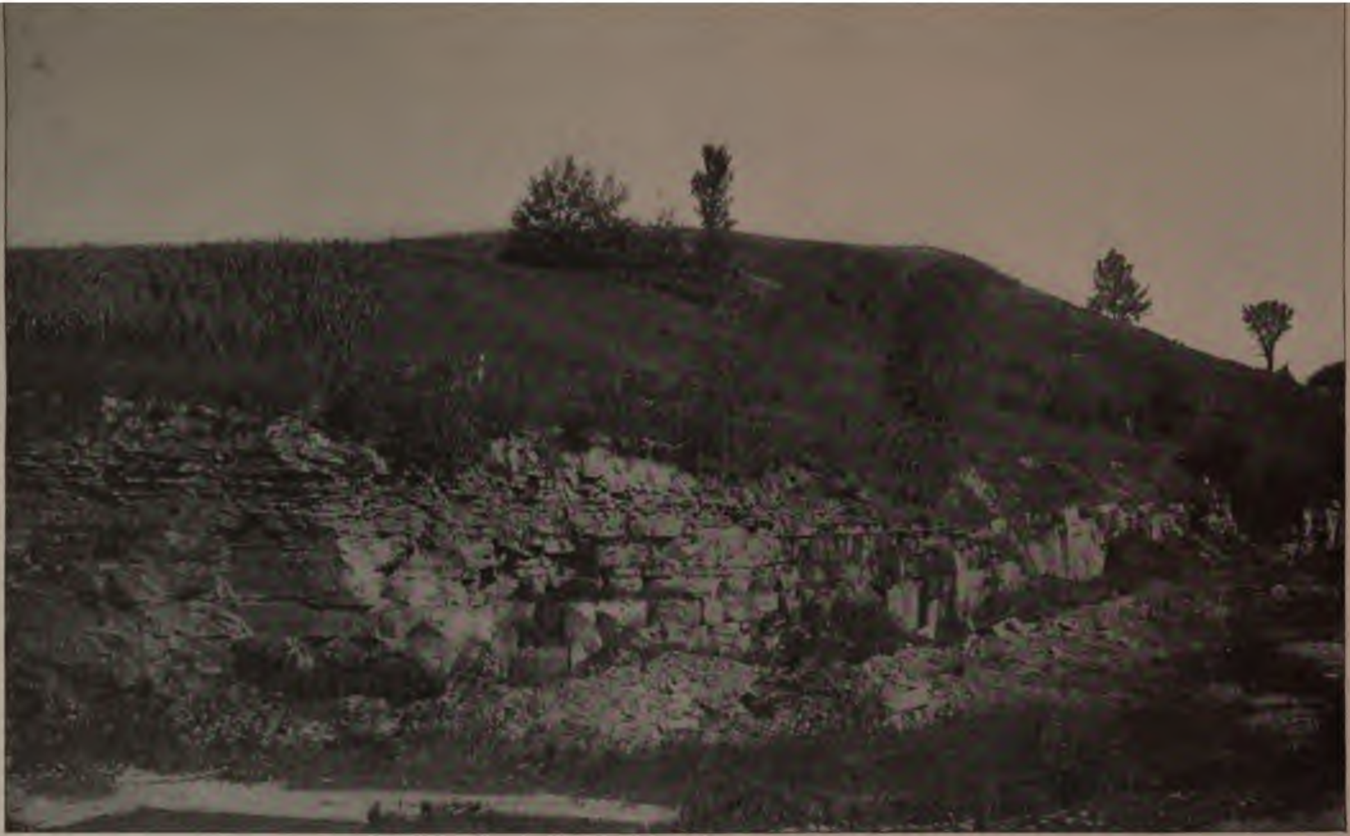
Silica	4.91
Ferric oxid	.53
Alumina	.48
Lime	51.82
Magnesia	1.16
Carbon dioxid	41.9
	100.8

The same quarry shows two thin layers of waterlime.

The group of Trenton limestones is of some importance in Herkimer county, but only the Birdseye and Trenton members are present.

Around Little Falls the Trenton is not over 4 feet thick according to Darton, but at Ingham Mills the rock is well exposed in the lime quarry of Sherman Butler (pl. 41), where nearly 15 feet of good stone can be seen. The better stone is bluish, fine grained and massive, but in the upper part of the quarry it passes into the Utica slate. The following analyses represent its composition, no. 1 being the lower massive rock and no. 2 the average of the quarry face.

	1	2
Silica	6.7	8.45
Alumina	3.03	2.72



H. Ries, photo.

Butler's quarry, Ingham Mills, showing Birdseye limestone passing upward into Utica shale

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Ferric oxid	.21	.84
Lime carbonate	89.15	84.6
Magnesium carbonate	tr.	3.42
	99.09	100.03

From Ingham Mills the Trenton limestone passes northwestward past Salisbury and Norway to the edge of the county, where it forms a belt whose width extends from Poland to Grant. A spur also extends from Poland southeast to Middleville, and it is quarried at Newport by G. S. Higgins, J. Dunn, N. Morey, W. W. Mosher, G. H. O'Connor, C. Smith, and D. Tuomey.

Jefferson county[1]

Probably one half the county is underlain by limestones, mostly of Trenton age, while additional small areas of pre-Cambrian age are known to occur. The Trenton limestone occupies a more or less triangular area, the towns of Clayton, Carthage, and Mannsville being approximately in the corners. The area is traversed by the several branches of the Rome, Watertown and Ogdensburg railroad.

The Calciferous sandrock, though known to occur in Jefferson county, is usually covered by the Birdseye. According to Emmons[2] the Calciferous is exposed 4 miles south of Theresa falls on the Watertown road, also 1½ miles east of French creek and near Depauville.

The Birdseye extends across the county from east to west, having a breadth of about 10 miles. Its northern edge passes through Depauville, and a point 2 miles south of Evans Mills on Indian river, thence to the great bend on Black river, and then to a point 2 miles southwest of Carthage. The Birdseye is thick bedded, and compact and usually of considerable purity. The total thickness of this member is not over 40 feet in Jefferson county.

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[1] Emmons, Ebenezer. Geol. 2d dist. N. Y. 1842. p. 368.
[2] Geol. 2d dist. N. Y. 1842. p. 380.

The Black river limestone rests on the Birdseye and derives its name from its occurrence along the Black river. It is very thick bedded, but at Watertown seems to be formed of lumpy masses. Its color is black, and not over 7 feet thick, being known to quarrymen as the 7-foot tier.

The Trenton limestone is divisible into two members, viz, a compact, black stone, and a gray, crystalline one. The former is sometimes evenly bedded, with masses of interbedded slate; while the gray is often more massive. The Trenton member first appears as a bluff at Watertown, and southward from there forms a series of terraced hills. Its total thickness is about 300 feet. Its boundaries extend from Champlain northwest to the Black river at a point 4 miles east of Watertown, thence to Henderson and then south to Ellisburg. The southern boundary passes nearly northeast from Mannsville in the direction of Adams, Whitesville and Tylerville. While the chief use of the different Trenton members has been for building, still it would make an excellent lime. It is quarried at Cape Vincent, Chaumont, Clayton, Pamelia, Redwood, Threemile Bay, Theresa, and Watertown.

Lewis county[1]

The Trenton limestone extends across the county in a northwesterly direction and follows the line of the Rome, Watertown and Ogdensburg railroad. It has been quarried at several localities, among them Leyden, Lowville and Collinsville.

The Birdseye member is well exposed along the road from Port Leyden to Leyden, 1½ miles south of the former locality on the land of Peter Snyder. The rock here is a fine grained, brittle, light gray stone, full of calcite eyes. An analysis of it made by D. H. Newland gave:

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[1] White, T. G. Report on relations of the Ordovician and Eo-Silurian rocks in portions of Herkimer, Oneida and Lewis counties. (*see* 51st an. rep't N. Y. state mus. 1: r21)

Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.

Silica	6.5
Alumina	1.67
Ferric oxid	.76
Lime carbonate	88.44
Magnesium carbonate	2.68
	100.05

This same stone outcrops for some distance along the railroad track south of this point.

South of Leyden and below the railroad level is a large quarry of black, finely crystalline limestone on the land of Mrs Christy. The stone has thus far been used for building purposes only. It probably represents the Trenton proper. It is of greater purity, however, as shown by the following analysis.

Silica	1.44
Alumina Ferric oxid	.83
Lime carbonate	97.36
Magnesium carbonate	1.04
	100.67

The Trenton limestone has been quarried for lime burning at Collinsville 3 miles north of Port Leyden. The rock here as exposed in Roberts's lime quarry is a coarse grained, gray stone, in thin layers 2 to 8 inches thick and often containing irregular partings of bituminous shale. They so predominate at times as to give the rock a shaly character, and such portions are discarded. The stone makes a white lime, as might be expected from its low silica and iron percentage. The composition of the stone as analyzed by Mr Newland is as follows:

Silica	3.09
Alumina	1.15
Ferric oxid	.49

Lime carbonate	94.11
Magnesium carbonate	1.63
	100.47

At Lowville the Trenton limestone is exposed in J. Waters's quarry, 1½ miles north of the town and along the Rome, Watertown and Ogdensburg railroad. The upper layers are black limestone with calcite spots, while the lower ones which are chiefly used are light gray, finely crystalline stone.

The composition of Mr Waters's limestone is:

Silica	3.96
Alumina	1.7
Ferric oxid	
Lime carbonate	91.27
Magnesium carbonate	3.78
	100.71

Livingston county[1]

The Helderberg rocks outcrop in the northern part of the county, but quarries are few. The Corniferous limestone has been quarried in the southeast corner of Caledonia township. The marls are perhaps of more importance than the limestones. The Wheatland deposit (mentioned under Monroe county) extends into Livingston, and another is known 1 mile east of Caledonia.

One good deposit has been opened up on the property of J. Simpson, 3 miles east of Mumford (pl. 42). The marl runs about 6 feet in thickness, and the upper, 20 inches to 2 feet, contains more clay than the lower. At the junction between the two are numerous shells. Below the 6 feet of marl there is said to be 6 feet of blue clay. Mr Simpson's marl has been shipped to Buffalo for the manufacture of carbon dioxid. The following is an analysis of the upper half.

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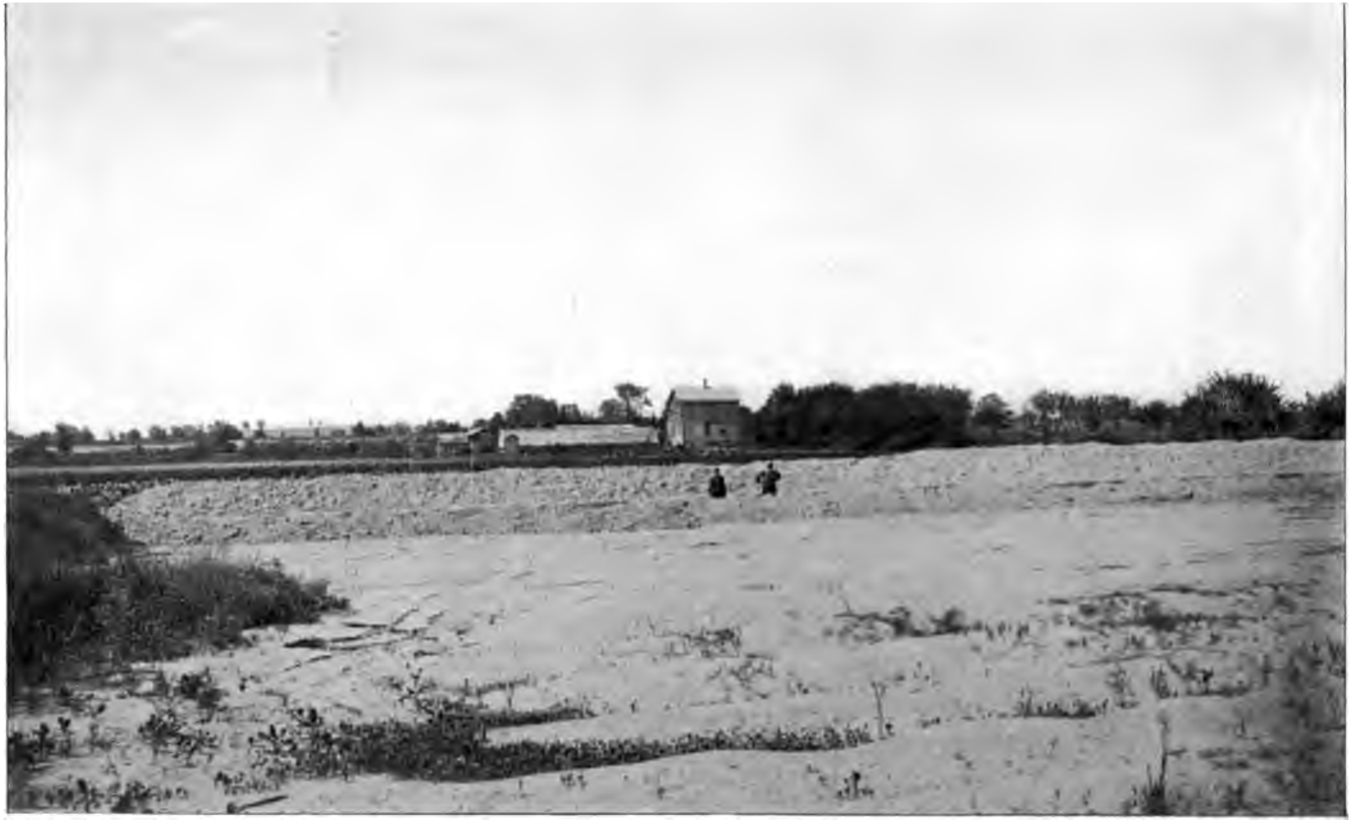
[1] Hall, James. Geol. 4th dist. N. Y. p. 459.



H. Ries, photo.

Marl pit on J. Simpson's property near Caledonia

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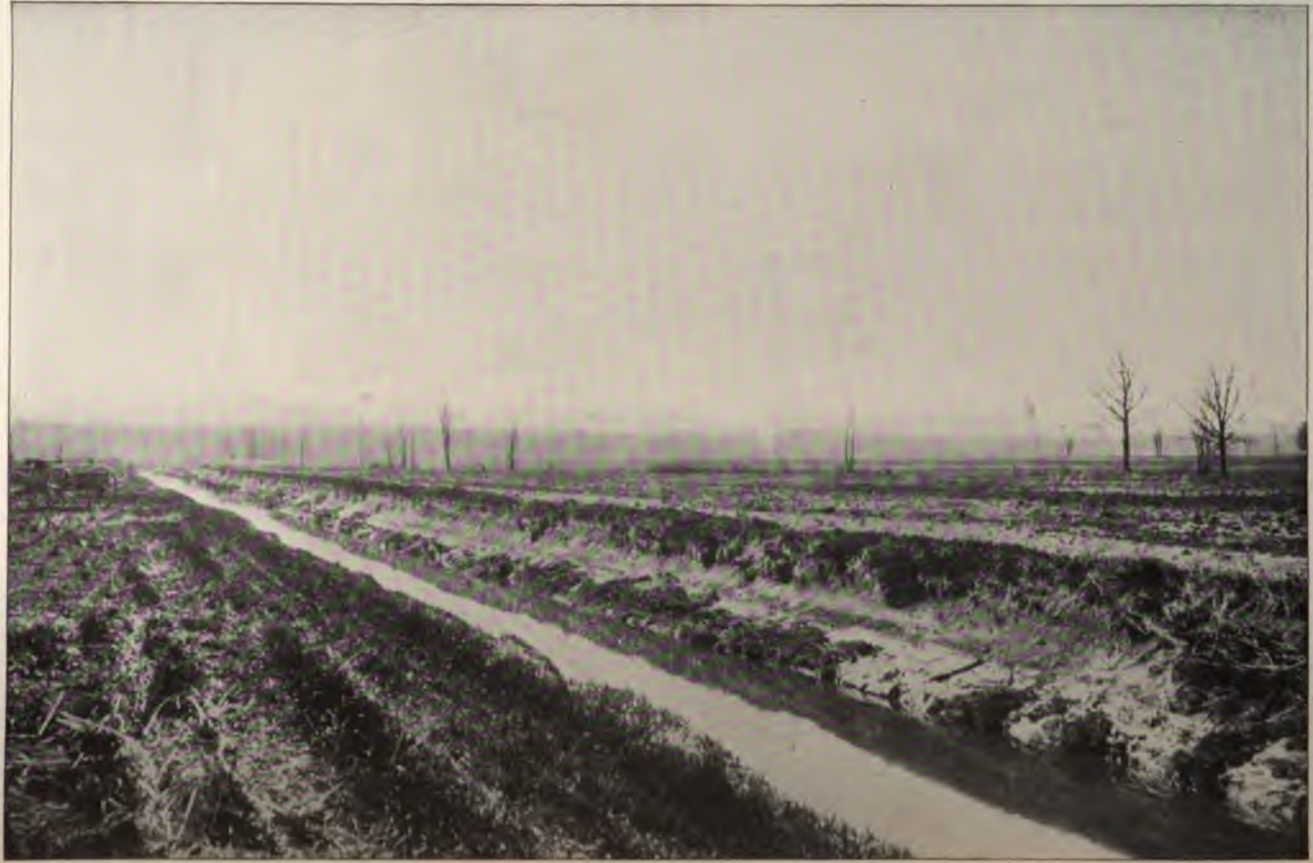
Plate 43

To face p. 793



H. Ries, photo.

Douglas ditch near Oniontown, showing marl bed underlying soil

Silica	1.1
Alumina Ferric oxid	1.5
Lime carbonate	97.4
Magnesium carbonate	tr
Insoluble	.026

It is reported that a Portland cement plant will be erected at this locality.

Madison county[1]

Madison county has limestones of Niagara and Lower Helderberg age and Quaternary marls.

The Niagara limestone crosses the county as a narrow belt from Bridgeport to near Oneida Castle, the former locality being situated on its northern edge. Owing to the heavy covering of drift, and the swampy character of the region in many places, outcrops are scarce. It is, however, quarried at Oneida by Mrs C. L. Faulkner and about 1¼ miles northeast of Canastota by Stout Bros. on the South Bay road.

The outcrops of Lower Helderberg limestone extend through the central part of the county in a rather sinuous belt, passing south of Chittenango and through Chittenango Falls, Perryville, Blakeslee, Cottons, Siloam, Stockbridge and Munnsville. Material for lime-making is quarried at a number of these points.

Cowaselon swamp is an extensive swampy area extending from the northern edge of Canastota westward to the county boundary. Owing to the richness of its soil, extensive ditches have been dug for draining the area, and in the excavation of these much marl has been exposed. One of the best sections is along the Douglas ditch and its feeders east and west of Oniontown, 3 miles north of west from Canastota. Here at least 6 feet of marl is exposed in the sides and bottom of this ditch. On F. Pennock's land west of Oniontown the marl is said to be 30 feet thick. The marl is covered by 3 feet to 4 feet of sand and organic matter. Whether or not clay underlies the marl is not known.

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[1] Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.

Marl also occurs on the land of J. C. Austin, 2 miles north of Canastota, and about a foot of it is exposed in the ditch in J. D. Conley's land, 1 mile north of town (pl. 43, 44). So far as known none of this marl has thus far been utilized. The following is an analysis of the material.

Silica	2.1
Alumina Ferric oxid	1.93
Lime carbonate	87.1
Magnesium carbonate	2.31
Insoluble and organic matter	11

Another deposit of marl is found south of Chittenango Falls.

Monroe county[1]

The Niagara is the most prominent and extensive limestone in the county, though Clinton, and Onondaga are also known. Quaternary marl is likewise found.

The Niagara limestone extends across the county as a belt several miles wide, its northern edge passing through the towns of Penfield, Brighton, Ogden, Gates and Sweden. The upper magnesian member generally forms the outcrops, and the weathered surface of the rock has a peculiar granular and spongy appearance. The upper member, or Guelph limestone, is a grayish brown, finely crystalline limestone containing numerous small cavities. The rock is very low in silica and has a large amount of magnesia, making it well adapted for refractory linings in furnaces. The lower beds of Niagara limestone are hard, compact and generally highly silicious in Monroe county. The Niagara shale underlies the Niagara limestone, and the transitional beds between the two sometimes furnish a natural cement rock. Beds of this nature outcrop at Shelby falls in the town of Barre.

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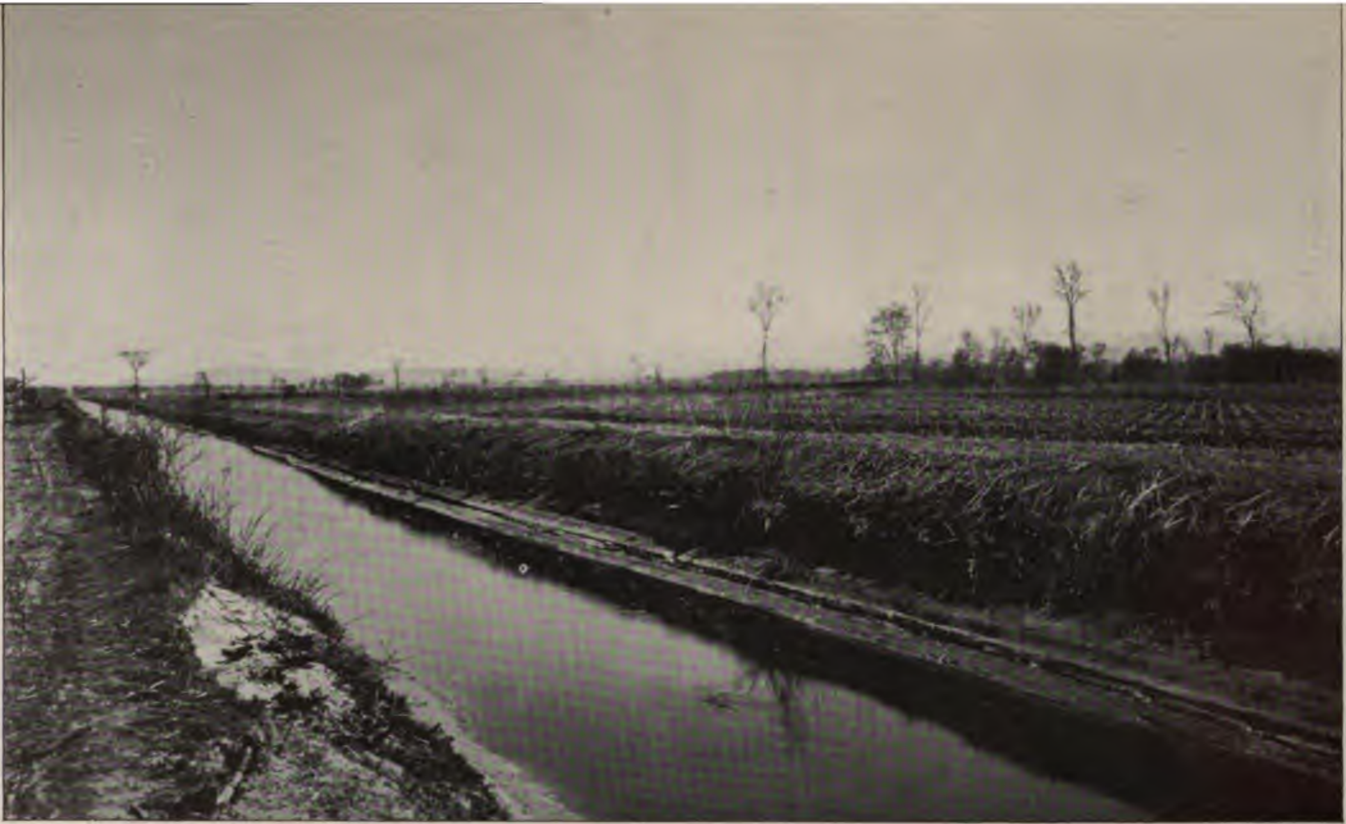
[1] Hall, James. Geol. 4th dist. N. Y. p. 422.



H. Ries, photo.

View across Cowaselon swamp, looking northwest

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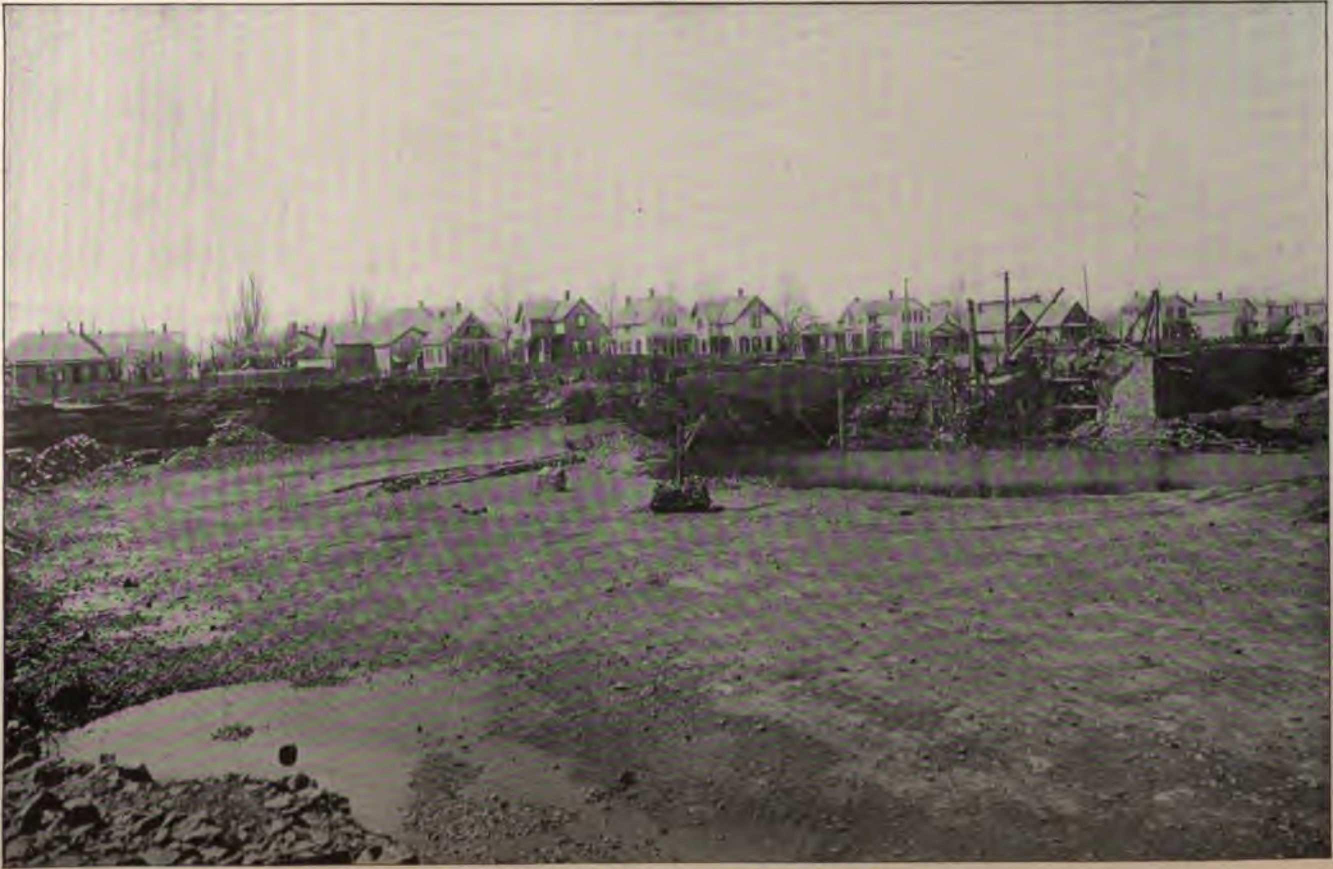
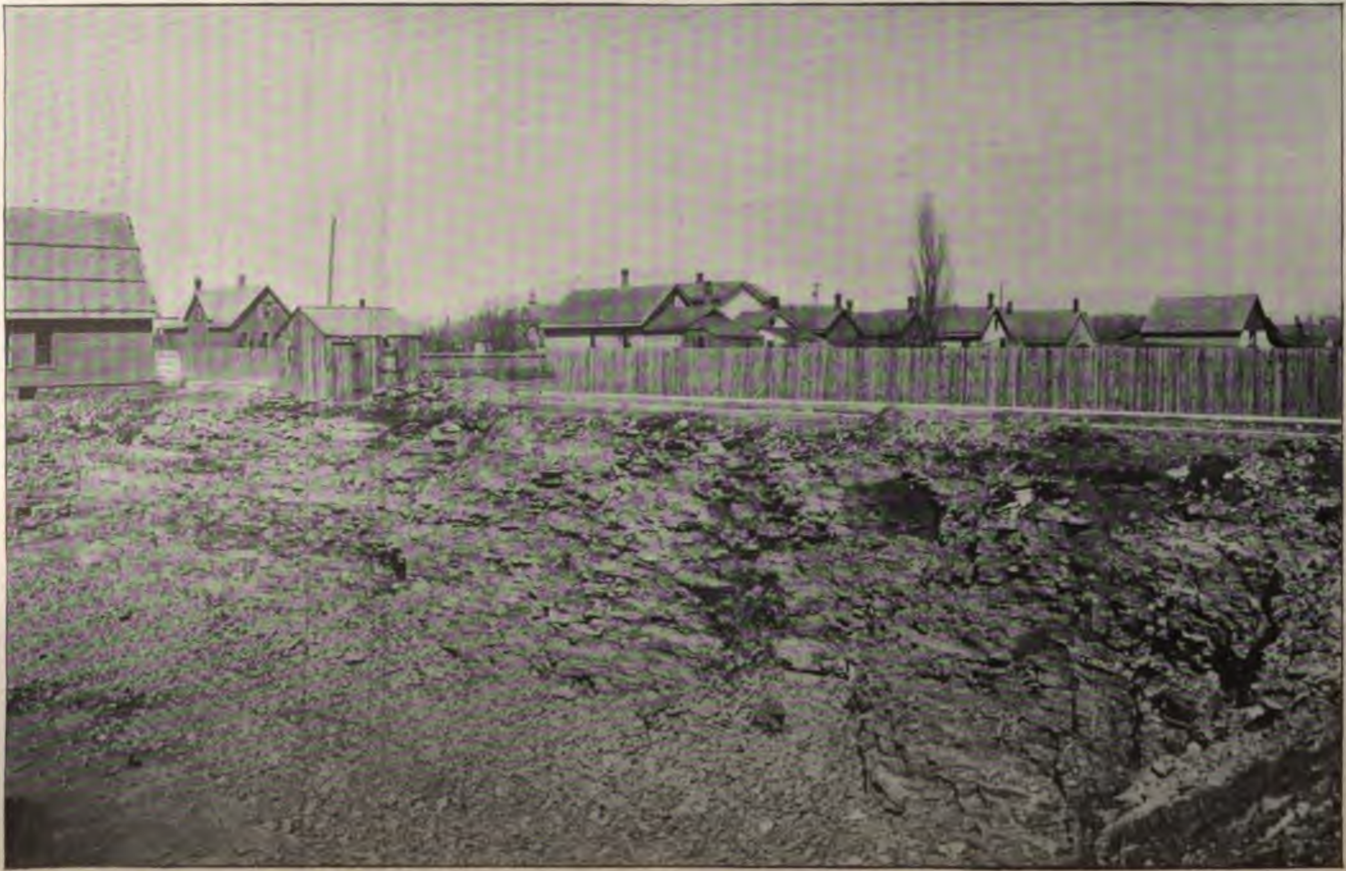


H. Ries, photo.

General view of quarries on Pike property, Rochester

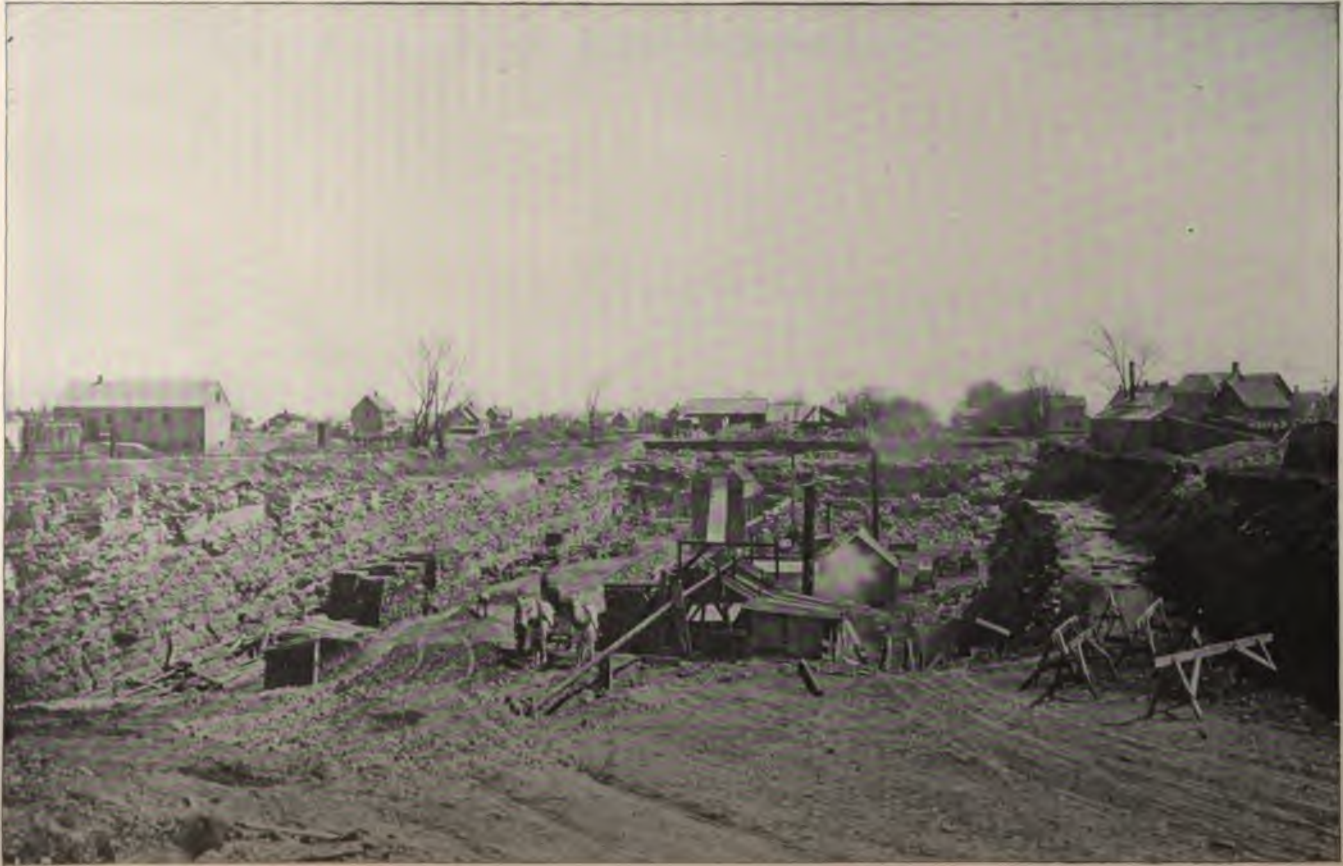


H. Ries, photo.

Section in quarry corner; Snyder and Frost avenues, Rochester

Plate 47

To face p. 795



H. Ries, photo.

Quarry of Whitmore, Rauber & Vicinus, W. Goodman street, Rochester

The lower member of the Niagara limestone is used only for building and road material, but the upper member, or Guelph, is extensively sought for lime-making.

In quarrying it for this purpose the massive layers are preferred to the cellular ones, as it is claimed that they yield a better grade of lime. Owing to its magnesian character, the lime is not very fat and consequently does not develop as much heat in slaking as one made from a pure stone.

A group of quarries is located at Snyder street and Frost avenue, Rochester, and known as the Pike quarries (pl. 45). The section exposed in the Guelph rock is about 18 feet thick, and the upper 5 feet, which is free from cavities, is said to make the best lime. Near the bottom is a 4 foot layer called by the quarrymen the "Hogback", which, it is claimed, does not make a good lime. Some stone is being drawn from this quarry to Mrs J. Hurd's limekiln at Jefferson and Seward avenues. The lime from this kiln is used chiefly for mortar but is also utilized to some extent by the glass works at Rochester.

The lower member of the Niagara limestone, which is not fit for lime-making, is extracted on North Goodman street near Northwest avenue, in the quarries of Foery & Kastner, Whitmore, Rauber & Vicinus, and Lauer & Hagaman. The stone is a medium bedded, hard, fine grained, silico-magnesian limestone.

The Guelph rock is quarried most extensively at Rochester, but also at Penfield and East Penfield. Good exposures occur in the quarry of Lauer and May at Brighton, 2 miles east of Rochester (pl. 48). The rock is used for lime and gives a lumpy product of yellowish color. The following analysis sets forth well its magnesian character and its comparative freedom from silica.

Silica	1.12
Alumina	.27
Ferric oxid	.39
Lime	29.38

Magnesia.	22.1
Carbon dioxid	47.39
	100.65

If this rock showed this same character at other points, it would show it to be an important bed, and to determine this additional analyses were made by Mr Newland. The first of these represents the average of several samples taken from Snow's quarry at Gates near [illegible]er.

Silica	.7
Magnesia.	20.05
Lime	30.5
Alumina	.95
Ferric oxid	.8
Carbon dioxid	45.24
Ignition.	.073
Undetermined	2.687

The last analysis is of a sample f[illegible]m the Copeland quarry in Rochester, collected by G. van Ingen.

Silica	.29
Alumina	.43
Ferric oxid	.46
Loss on ignition	.07
Lime carbonate	56.01
Magnesium carbonate	43.3
	100.56

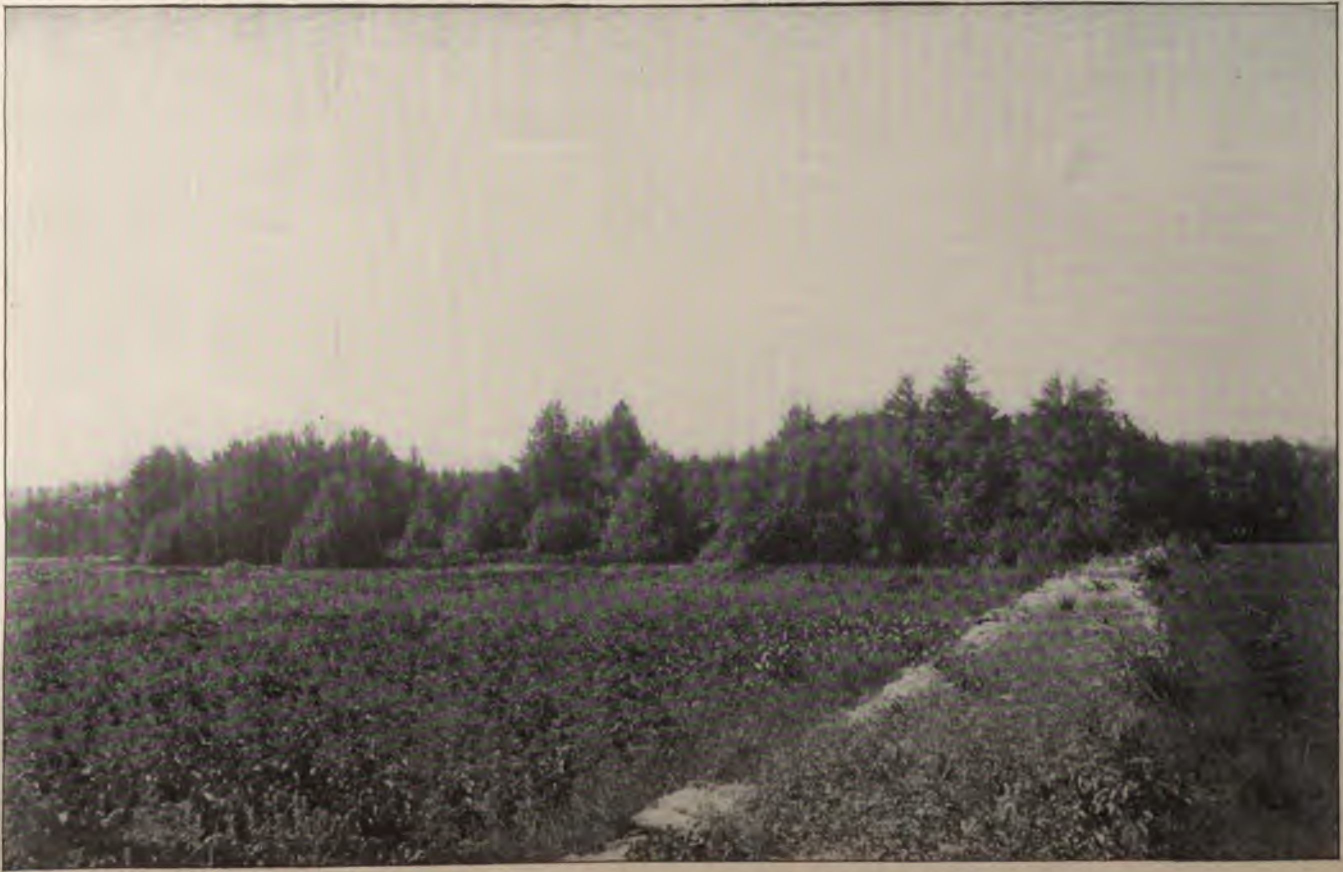
This shows the rock to be an almost pure dolomite.

The Clinton also occurs in Monroe county, and is to be seen outcropping at the middle falls in the gorge of the Genesee river

To face p. 796

Plate 49

To face p. 797



H. Ries. photo.

Outcrop of tufa overgrown by cedars on farm of Oliver Allen, near Mumford at Rochester. No analyses of it are available, but it is thin and unimportant.

The Lower Helderberg limestone occurs sparingly along the southern edge of the county, but is not quarried.

The Quaternary marls and tufas are of some importance in the county. The tufa is at times sufficiently extensive to be used for burning into lime, and it is also massive enough for structural work, a church having been constructed of it at Mumford.

Marl occurs at several localities in the county. Perhaps the largest area is that along Allens creek near Wheatland, this bed extending into Livingston county. At some points the marl is overlain by calcareous tufa to a depth of 3–4 feet. Hall[1] gives the length of the marl swamp as 3 miles, and its breadth as from half a mile to 1 mile. At Mumford the tufa is well exposed in a cedar swamp on the farm of Oliver Allen, ¼ mile east of Mumford station. It contains stems and leaves of cedar (pl. 49). Its composition is as follows:

Silica	.5
Alumina Ferric oxid	2
Lime carbonate	94.1
Magnesium carbonate	2.3
Insoluble	.5
	99.4

Under the tufa is a bed of marl. On the property of Mr Ward, a florist in Mumford, tufa was encountered in sinking a well, but at this point it was underlain by blue clay. Marl also underlies the cemetery at Mumford.

According to Prof. Hall, another extensive deposit of marl occurs along Mill creek, beginning at its source, and extending to Cady sound. Tufa forms in exposed situations along the deposit.

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[1] Geol. 4th dist. N. Y. p. 429.

Again in the town of Riga on the land of Mr Knowley, a deposit of marl of unknown depth covers 30 or 40 acres. It has been penetrated 10 or 15 feet without finding bottom. The upper 2 feet is very pure, but the lower part is sandy.

The marl has been used for enriching soils, with very good results at several points in the county.

Montgomery county[1]

Good exposures of the Calciferous occur near the New York Central railroad at Amsterdam and St Johnsville, Canajoharie and Tribeshill.

According to Darton the Trenton limestone reaches its maximum thickness at Fort Plain, where it is 9 feet, but decreases to 7 feet at St Johnsville. The limestone varies sometimes, being massive at Tribeshill, and at other places shaly. In the Tribeshill quarries 12 to 15 feet of massive stone is exposed. Other exposures are seen in the quarries north of Amsterdam.

At D. C. Hewitt's quarry, 1 mile north of Amsterdam, the Trenton rock has been used for lime. In the upper quarry the stone is coarse grained, and the layers in upper portion of the quarry are quite impure and shaly. The rock from this upper quarry burns to a brown lime. In the lower quarry, which is just below Hewitt's limekiln, the stone is much purer and more massive than that of the upper quarry. The lower layers are harder, are light gray and are said to make a whiter lime. Under this comes a bed of lime rock which is practically non-slaking and seems to have hydraulic properties. The lime made at this quarry is fairly white. The composition of the lower limestone runs:

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[1] Darton, N. H. Preliminary description of the faulted region of Herkimer, Fulton, Montgomery and Saratoga counties (*see* 14th an. rep't N. Y. state geol. p. 33)

—— Geology of Mohawk valley in Herkimer, Fulton, Montgomery and Saratoga counties. (*see* 47th an. rep't N. Y. state mus. p. 603)

Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.

Silica	6.13
Alumina	.79
Ferric oxid	.61
Lime carbonate	88.49
Magnesium carbonate	2.45
	98.47

The upper beds showed 8.92% of insoluble matter. There is evidently considerable variation in the upper layer, as a comparison of the foregoing analysis with the first of the following three shows. They were made by J. M. Sherrerd and published in 19th annual report U. S. geological survey, pt 6.

	Upper layer	Intermed.	Lower
Silica	1.25	3.82	5.68
Ferric oxid Alumina	3	1.08	2.76
Lime	52.78	52.46	52.12
Magnesia	.....	.....	.....
Undetermined (CO_2?)	42.97	42.64	39.44

Another limestone quarry has been opened by George Ross on the eastern edge of the town. The rock has thus far been used as building stone. It contains some sandy streaks, which could be separated if the stone were to be burned into lime. The average composition of the stone is:

Silica	7.46
Alumina	2.48
Ferric oxid	1.07
Lime carbonate	71.76
Magnesium carbonate	18.19

This rock is probably Calciferous and not Trenton, judging from its magnesian character. Portions of the rock in the eastern end of the quarry run as low as 4% in insoluble matter.

Other quarries have been opened at Canajoharie, Palatine Bridge, and St Johnsville there being a large number at the last town.

New York county[1]

There is an extensive exposure of white crystalline limestone of Cambro-Silurian age on the west side of the Harlem river, at and south of Kingsbridge; several exposures also occur in Morrisania, and at other points in the county.

The two following analyses of the white limestone from Kingsbridge were kindly furnished by Mr G. A. Stone:

Silica	7.15	10.2
Ferric oxid and alumina	1.06	3.33
Lime	39.57	27.32
Magnesia	10.02	17.99

Niagara county[2]

Limestone passes through the towns of Royalton, Lockport, Cambria and Lewiston. In this county the Guelph, or magnesian member, is missing, but the lower member is of increased thickness. The lower beds overlying the shale are apt to be somewhat silicious, but the upper ones are a crinoidal limestone of greater purity.

The following section of beds composing the Niagara limestone at Lockport is given by Prof. Hall.[3]

5 Thinly laminated, blackish gray limestone with thin laminae of bituminous shaly matter, the whole exhibiting a tendency to a concretionary or contorted structure and the surface of the layers marked by small knobs.

4 Grayish brown bituminous limestone, the lower part with irregular cavities containing spar.

3 A dark colored limestone with cavities and veins of spar often concretionary.

2 Irregularly thick bedded limestone of a light gray color, also containing cavities lined with spar.

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[1] Kemp, J. F. Geology of Manhattan island. (*see* Trans. N. Y. acad. sci. 1888. 7: 49–64)

——— Merrill, F. J. H. Crystalline rocks of southeastern New York. (*see* 50th an. rep't N. Y. state mus. 1898. 1: 2–31)

Mather, W. W. Geol. 1st dist. N. Y. 1843.

[2] Hall, James. (*see* Geol. 4th dist. N. Y. p. 440)

——— Grabau, A. W. Guide to the geology and paleontology of Niagara Falls and vicinity. (*see* Bul. 45. N. Y. state mus. 1901)

[3] Geol. 4th dist. N. Y. p. 89.

1 Encrinal limestone containing numerous crinoid stems. Light gray in color but often spotted with red.

Samples for analyses were taken by the writer from a quarry by a limekiln, 1½ miles east of Lockport and along the canal. The rock in this excavation is a light gray, fine grained, massive limestone containing numerous fossils, which often occur in large aggregates. The upper layers of the quarry are thinner and more argillaceous than the lower ones.

The composition of the Niagara limestone in this quarry is shown by the following analysis made by D. H. Newland.

Silica	7.09
Alumina	2.57
Ferric oxid	.96
Lime carbonate	56.19
Magnesium carbonate	33.42
	100.23

South of the town of Niagara Falls the Niagara limestone is quarried for burning into lime. The quarry is owned and operated by William Messing. The following is an analysis of his stone made by the writer.

Lime	32.21
Magnesia	17.45
Alumina	1.3
Ferric oxid	.75
Silica	1.7
Carbon dioxid	46.79
	100.2

Oneida county[1]

The Helderberg limestones extend across the southern part of the county and are crossed by both the Utica, Binghamton branch and Utica branch of the Delaware, Lackawanna & Western railroad.

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[1] Prosser, C. S. & Cumings, E. R. Sections and thickness of the Lower Silurian formations on West Canada creek and in the Mohawk valley. (*see* 15th an. rep't N. Y. state geol. p. 23)

White, T. G. Report on relations of the Ordovician and Eo-Silurian rocks in portions of Herkimer, Oneida, and Lewis counties. (*see* 51st an. rep't N. Y. state mus. 1: r21)

Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.

In the eastern part of the county the Trenton limestone extends from Poland to Boonville in a belt several miles wide following the line of the Rome, Watertown & Ogdensburg railroad. The Trenton has been quarried at Prospect along West Canada creek. Prof. Smock states[1] that a sample tested contained 94.82% lime carbonate.

An analysis from this same quarry made by J. D. Irving gave:

Silica	2.59
Alumina	1.21
Ferric oxid	.61
Lime	52
Magnesia	1.04
Carbon dioxid	42
	99.45

Prof. A. H. Chester, of Rutgers college, New Brunswick (N. J.) has kindly furnished the writer with the following analyses.

LOCALITIES	CaO	MgO	Fe_2O_3 and Al_2O_3	CO_2	SiO_2	S	TOTAL
1 Quarries near Clinton, Oneida co. N. Y.	48.68	1.84	(2) 1.64	40.29	7.23	.21	99.89
2 Quarry near Clinton (dark)	52.53	.69	.86	42.08	1.92	.....	97.53
3 Same " (light)	35.25	8.94	....	37.82	....	.....	....
4 " " (dark)	43.22	6.08	....	40.65	....	.....	....
5 Another "	48.82	1.48	....	39.99	....	.....	....
6 " "	50.25	1	1.5	40.49	5.53	.8	99.07
7 Oriskany Falls, Oneida co. N. Y.	50.47	.83	1.55	40.57	5.56	.21	99.19
8 Oriskany Falls, Oneida co. N. Y.	52.69	.84	1.55	42.33	2.57	.14	100.12
9 Oriskany Falls, Oneida co. N. Y.	50.25	1.11	2.14	40.7	5.66	.18	100.04
10 Oriskany Falls, Oneida co. N. Y.	50.8	1.01	1.35	41.02	5.46	.12	99.76
11 Oriskany Falls, Oneida co. N. Y.	50.93	.85	1.38	40.87	5.82	.07	99.92
12 Quarry near Clinton	53.52	.46	.95	42.54	2.48	.04	99.99

The Niagara limestone extends eastward from Madison county as a thin belt passing through Oneida Castle and Vernon.

The Lower Helderberg is prominent in the southern part of the county, with quarries at Oriskany Falls and Caseville.

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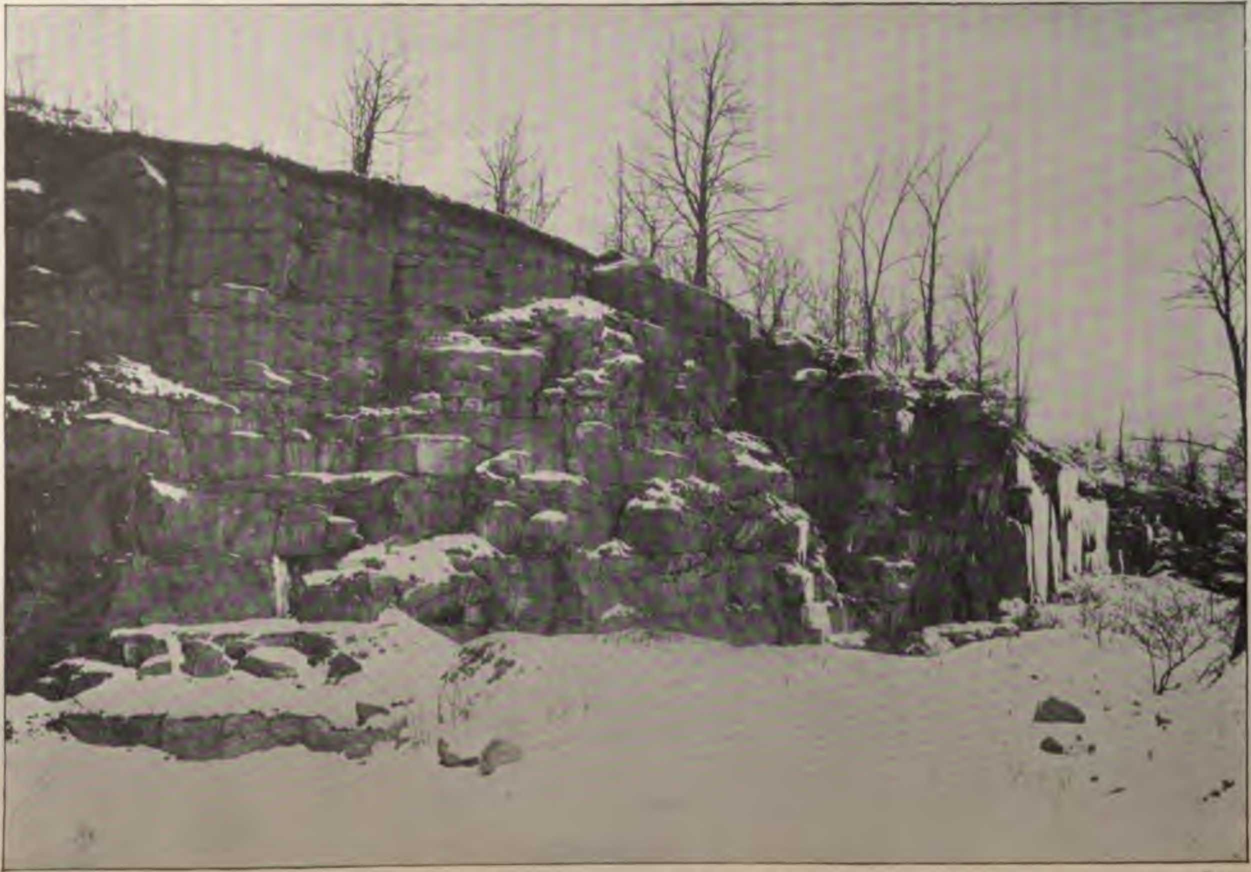
[1] Bul. 10. N. Y. state mus. p. 246.

Plate 50



H. Ries, photo.

Upper quarry, Putnam estate, Oriskany Falls

At the former locality there are two quarries just north of the town and close to the Clinton and Binghamton railroad. Both are owned by the Putnam estate, and the upper quarry (pl. 50), or that nearest the town, is used for lime, while the lower one is worked partly for road metal and partly for flux used at the Franklin furnace near Clinton.

The following analysis represents the average of samples taken from the lime quarry.

Silica	4.45
Alumina Ferric oxid	.3
Lime carbonate	89.4
Magnesium carbonate	5.76
Insoluble	4.75

Onondaga county[1]

Some of the largest limestone quarries in New York state are situated in Onondaga county. The limestones quarried are the Niagara, Lower Helderberg and Upper Helderberg. The purest limestone in the county is furnished by the Stromatopora beds and known as the "diamond blue" rock. Much stone of good grade is however also furnished by the Lower Helderberg rock, notably west of Syracuse.

The Niagara limestone is exposed at several places from the northwest corner of the county to Bridgeport. It generally forms a low ridge. At Diedrich's quarry in Lysander village, where it has been operated for a number of years, the magnesian Niagara limestone is 5 feet thick and of dark gray color. Near Baldwinsville it is 4 feet thick but rather shaly. In Cicero it is 3 feet thick and was formerly used for making lime. As a rule the Niagara limestone can be easily quarried.

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[1] Luther, D. D. Economic geology of Onondaga co. (*see* 15th an. rep't N. Y. state geol. p. 237)
Lewis, F. H. The Empire portland cement plant at Warner, N. Y. (*see* Eng. rec. 38, no. 7, p. 136)
Schneider, P. F. Limestones of central New York. (*see* Stone, 18: 26)
Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.

The Lower Helderberg rocks of Onondaga county are mostly dark blue and fine grained, occurring in beds 1 to 5 feet thick. They weather to a bluish gray. Most of them are fairly pure but at times contain some magnesia or clayey material. The pure beds are the important lime producers and are used for structural work in the county.

Two beds of hydraulic limestone lie near the top of the group, and according to Luther are often separated by 4 feet of impure limestone. In the eastern part of the county the upper layer is 4 feet thick, but it pinches out in the Splitrock quarry west of Syracuse to reappear again near Marcellus Falls, where it is 2 feet 10 inches thick in Watkins quarry, and reaches 4 feet in Corrigan's quarry at Skaneateles. As at the latter place it is only separated from the lower bed by a shaly layer, the two practically form one bed 9 feet 6 inches thick.

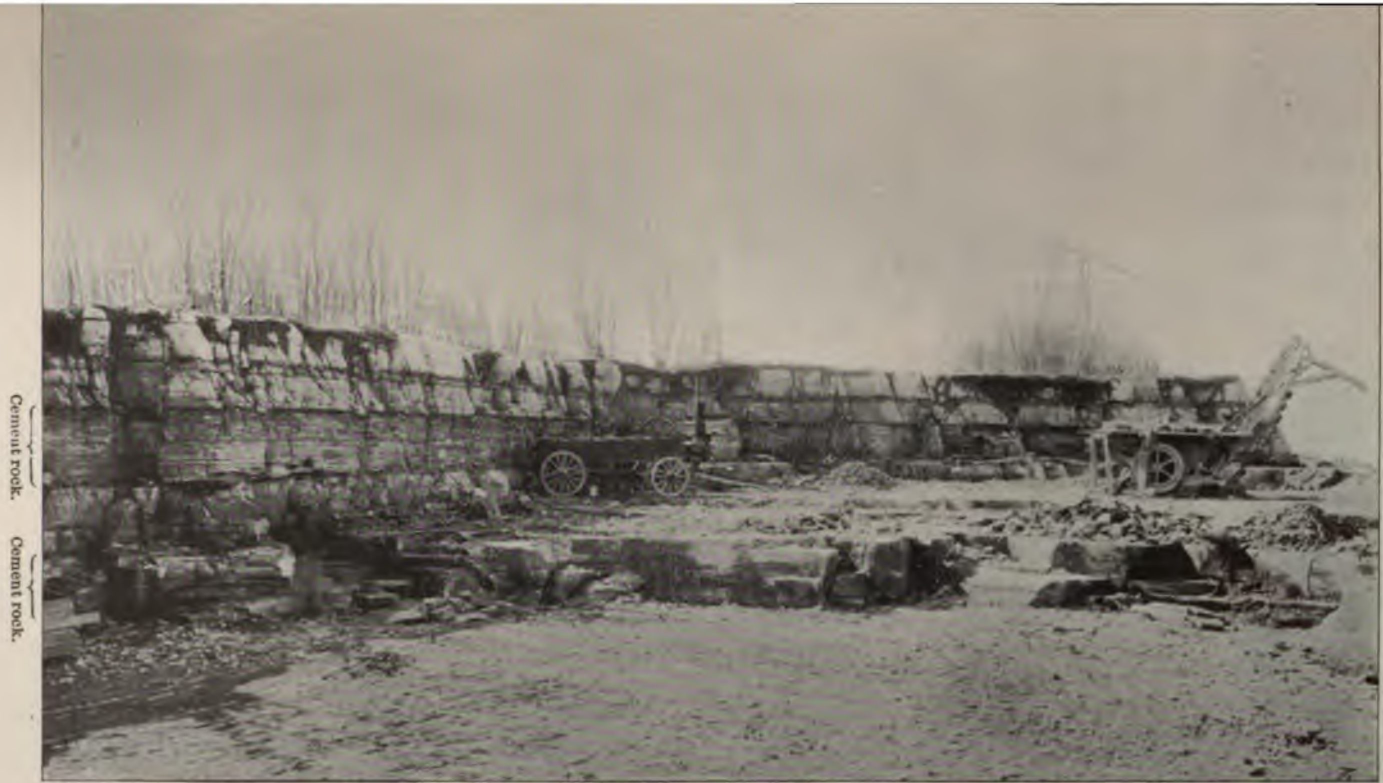
At Manlius the beds are separated by 4 feet of blue limestone and at Street's quarry near Onondaga Hill by 1 foot 8 inches, at Marcellus Falls by 1 foot 7 inches, and at Skaneateles they are together.

Luther gives the following thicknesses for the lower waterlime layer in Onondaga county.

	FEET	INCHES
Manlius, J. Behan's quarry	4	
Jamesville, E. B. Alvord	4	
Brighton, Britton and Clark	5	
Skaneateles, Corrigan's quarry	5	

At Splitrock the upper member occurs in the southeastern part of the quarry but is wanting in the western portion, its place being occupied by a 9 foot bed of blue limestone.

The hydraulic limestone in Onondaga county is brittle, compact, fine and even grained. It is dark colored with a conchoidal fracture but weathers to a light color. The beds are generally well defined but do not as a rule contain any fossils. The rock was discovered in 1818 in connection with work on the Erie canal. As in other cases attempts were made to burn the stone



H. Ries, photo.

Behans quarry, Manlius

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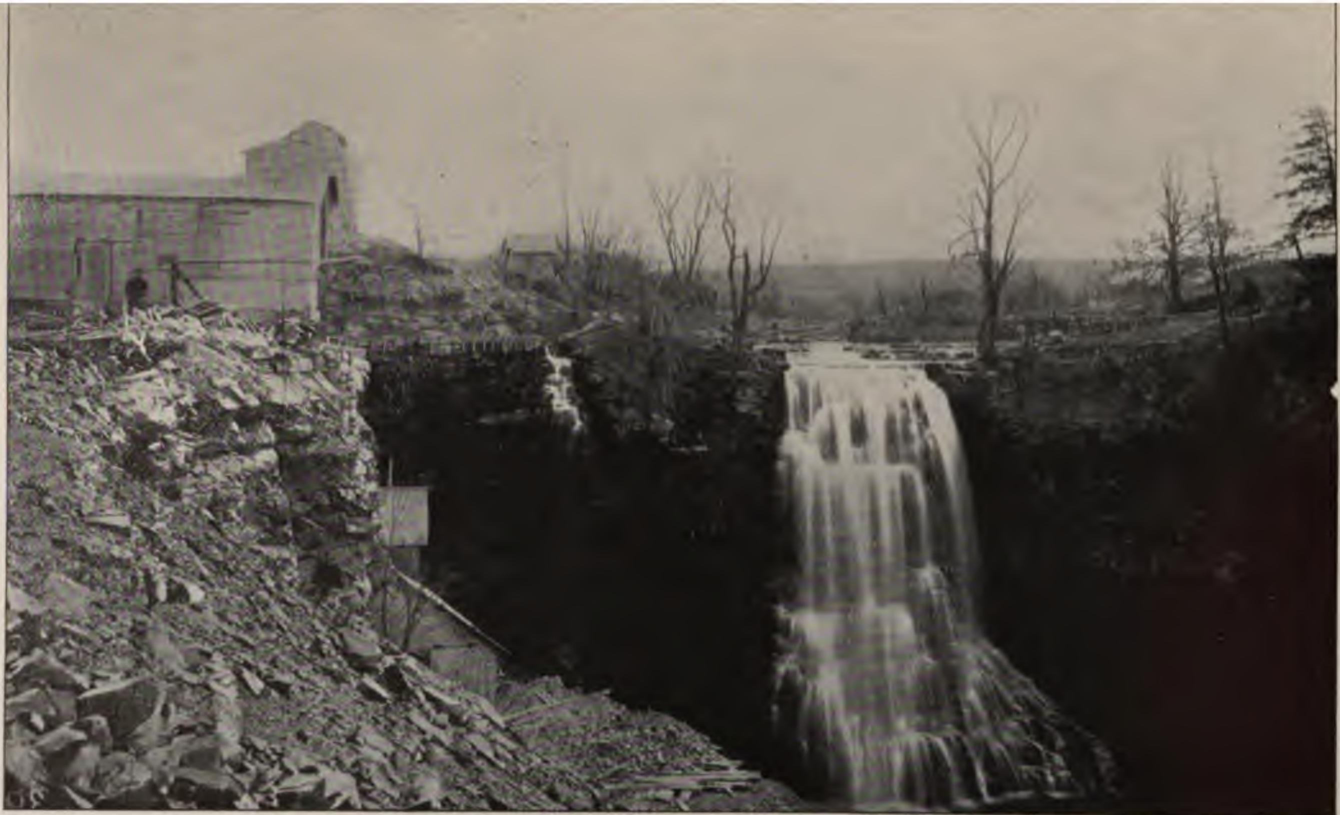


H. Ries, photo.

Brown's cement kiln and mill on left near Manlius

Plate 53

To face p. 805

H. Ries, photo.

Upper quarry, Alvord & Co., Manlius. Stone used by Solvay process co.

Plate 54

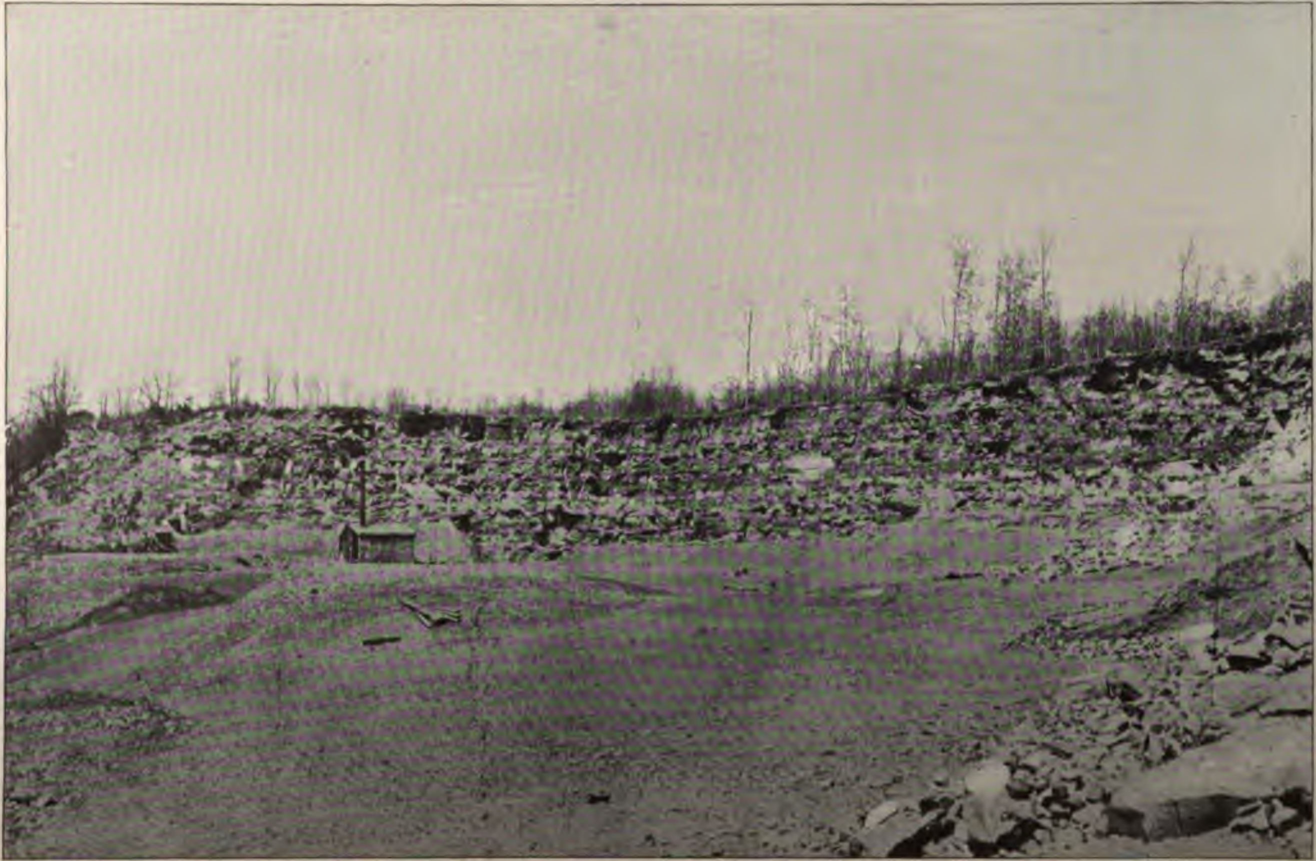
To face p. 805

H. Ries, photo.

A. E. Alvord & Co.'s quarry south of Jamesville, yielding limerock and waterlime

Plate 55

To face p. 805



H. Ries, photo.

" Swamp " quarry of Alvord & Co., Jamesville for lime, but it was found that it would not slake. The cement rock quarries are generally near the summit of the Helderberg escarpment, and covered by a little other rock, which is first stripped and used for building purposes or road material.

The limestone obtained from the Stromatopora beds is locally known as diamond rock or diamond blue, and is the stratum commonly used for the manufacture of lime; the same kilns are used for burning either lime or cement. Those used in Onondaga county are oval with a diameter of 10 feet at the top, 12 in the middle and 3½ at the bottom. They are 28 to 42 feet deep and are generally built of limestone with a lining of fire brick. In starting the kiln a cord of 4 foot wood is put in the bottom, over this 4 inches of anthracite coal, then 1 foot of limestone, more coal and alternating layers of stone and coal to the top. It takes 10 tons of coal and 15 cords of stone to fill a kiln, and this gives 1500 bushels of lime. After the kiln has been burning two or three days the first draw of 250 to 300 bushels can be made at the bottom of the kiln. The cement is of course ground before use. The most important producers in the county are: A. E. Alvord of Syracuse, quarry and kilns at Syracuse; J. Behan estate, quarry and kilns at Manlius; E. B. Alvord & Co. Jamesville; Britton & Clark, Rock Cut.

Most of the limestone quarried in the county is used by the Solvay process co., of Syracuse, in the manufacture of soda ash. This firm has a very large quarry at Splitrock, about 5 miles west of Syracuse, from which it has been taking over 250,000 pounds annually. Recently the supply has been decreasing, and the company is obtaining stone in part from A. E. Alvord & Co.'s quarry at Manlius.

No. 1 shows the composition of lime made from the stone in E. B. Alvord & Co.'s quarry at Jamesville, the analysis being made by F. E. Engelhardt.

Lime	91.93
Magnesia	3.06

Insoluble	1.88
Sulfuric anhydrid	.73
Ferric oxid and alumina	2.03

The composition of the limestone in Alvord's quarry is:

Silica	1.6
Alumina and ferric oxid	.7
Lime carbonate	97
Magnesium carbonate	1.11

This same quarry also contains several layers of cement rock, of which the following are analyses.

	Upper layer	Lower layer
Silica	10.97	10.95
Alumina	4.46	5.32
Ferric oxid	1.54	1.3
Lime	27.51	30.92
Magnesia	16.9	13.64
Carbon dioxid	37.94	38.31

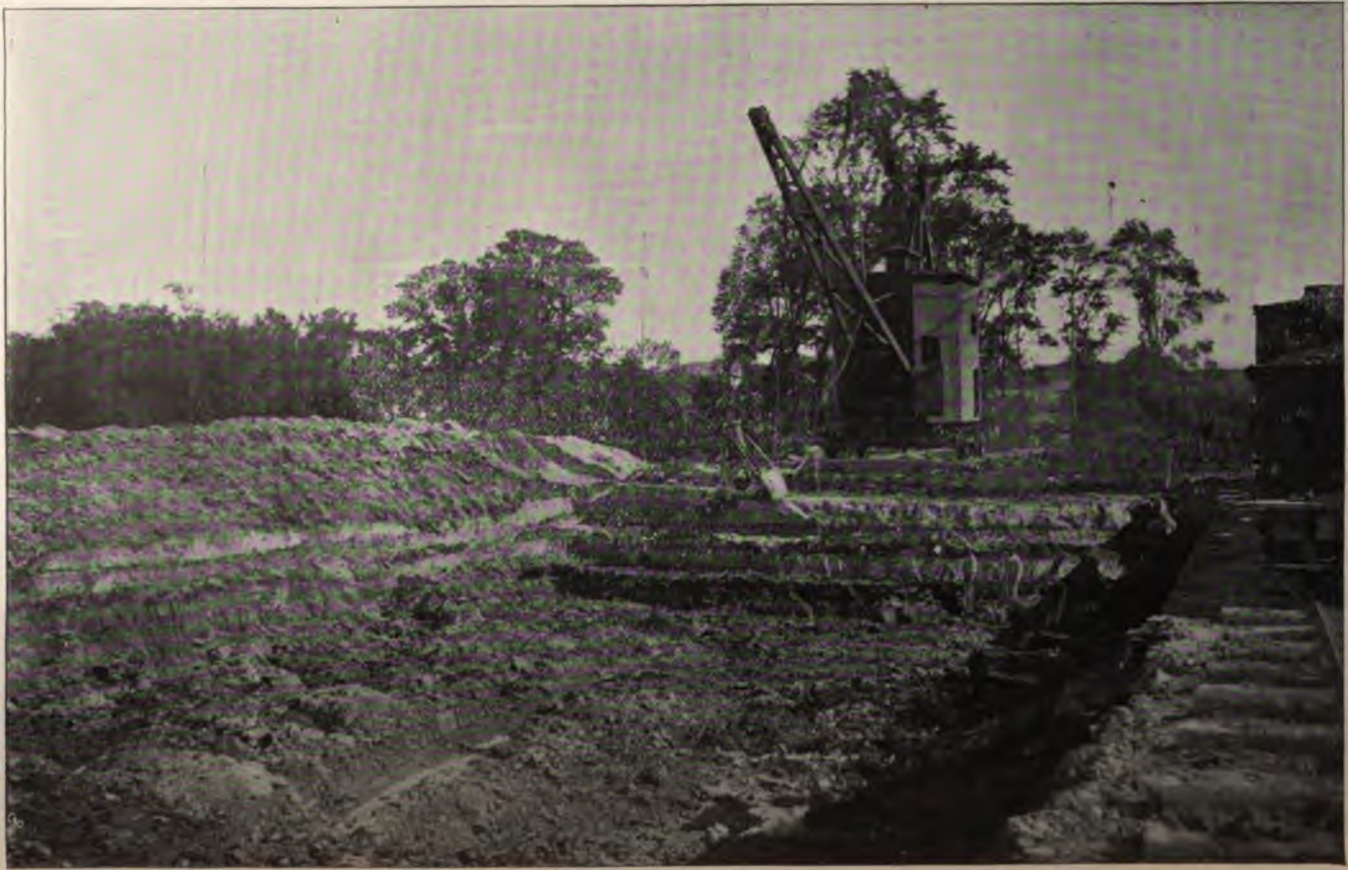
The composition of the blue lime in the Splitrock quarry of the Solvay co. is as follows:

Silica	5.35
Alumina	.56
Ferric oxid	.61
Lime carbonate	85.41
Magnesium carbonate	18.86

The Upper Helderberg, in Onondaga is a light gray semicrystalline limestone, the layers being separated by partings of shale. The rock is at times variable in its character and may at times

Plate 56

To face p. 807



H. Ries, photo.

Marl pit at Warners

become argillaceous. Cherty layers are sometimes common in the upper part of the formation.

The chief value of the Corniferous is as a building stone, though many portions of it are adapted to the manufacture of lime. Many quarries have been opened in it, and the largest now in operation is at the Indian reservation in the Onondaga valley.

The Onondaga group of limestones has a total thickness of 60 feet at the eastern edge and 70 feet at the western edge. The Corniferous is usually found at the top of the Helderberg escarpment. At Green lakes, 2 miles north of Jamesville, 25 feet of Onondaga stone is exposed. At the Splitrock quarries about 12 feet of Corniferous is exposed in the southwest corner, and in A. E. Alvord's quarry, ½ mile east of Manlius, 17 feet 6 inches is exposed. Maylie's quarry, ½ mile southeast of Marcellus, shows the upper layers of the Corniferous, and they are also to be seen in John Clancy's and M. Hogan's quarry near there. Maylie's stone is used in part for lime.

Marl abounds[1] in many of the small lakes around Dewitt and Manlius. Cicero swamp is underlain by an extensive deposit, and the marshes near Dewitt and Manlius also contain it. Other beds are in Camillus, Elbridge and southern part of Van Buren near the Erie canal.

Two important Portland cement plants, the one at Jordan, the other at Warner utilize this material.

They are described in another portion of the report.

Ontario county[2]

The Lower and Upper Helderberg cross the county, the northern boundary of the belt coinciding approximately with the

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[1] Luther, D. D. Economic geology of Onondaga county. (*see* 15th an. rep't N. Y. state geol. p. 237)

[2] Clarke, J. M. Brief outline of the geological succession in Ontario county, N. Y. (*see* 4th an. rep't N. Y. state geol.)
Hall, James. Geol. 4th dist. N. Y. p. 453.

Lehigh Valley railroad. Quarries have been opened in it at Phelps.

Hall[1] states that marl underlies the marsh bordering Flint creek south of the village of Bethel, and probably occurs under the swamp near Victor, as well as in the swamps at the heads of Hemlock and Canadice lakes.

Orange and Rockland counties[2]

In Rockland and Orange counties there begins another series of belts of the Cambro-Silurian limestone formation, which extend in a northeasterly direction. These same belts continue across the river into Dutchess county and also extend up into Columbia county. In the latter, however, they are so unimportant as not to be worth considering.

The Cambro-Silurian limestones are found at several places in Orange county. One area occurs around Central Valley (pl. 57) and Turner, extending thence westward to Monroe. It is finely crystalline, light bluish gray, and rather silicious; still it is used for lime. Another area extends from a point about 2 miles south of Sugarloaf past Stone Bridge, Warwick and New Milford into New Jersey.

Its character in this area is similar to that of the limestone around Monroe and Turner, and a quarry has been opened in it 2 miles south of Goshen, on the road to Warwick.

It may at times become quite silicious, showing as much as 18% silica, and there may also be a variation between the different

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[1] Geol. 4th dist. N. Y. p. 458.

[2] Barrett, S. T. Notes on the Lower Helderberg rocks of Port Jervis, N. Y. (*see* Am. jour. sci. 3d ser. 13: 385)

Darton, N. H. Area of Upper Silurian rocks near Cornwall Station, eastern central Orange county, N. Y. (*see* Am. jour. sci. 1886. 3d ser. 31: 209)

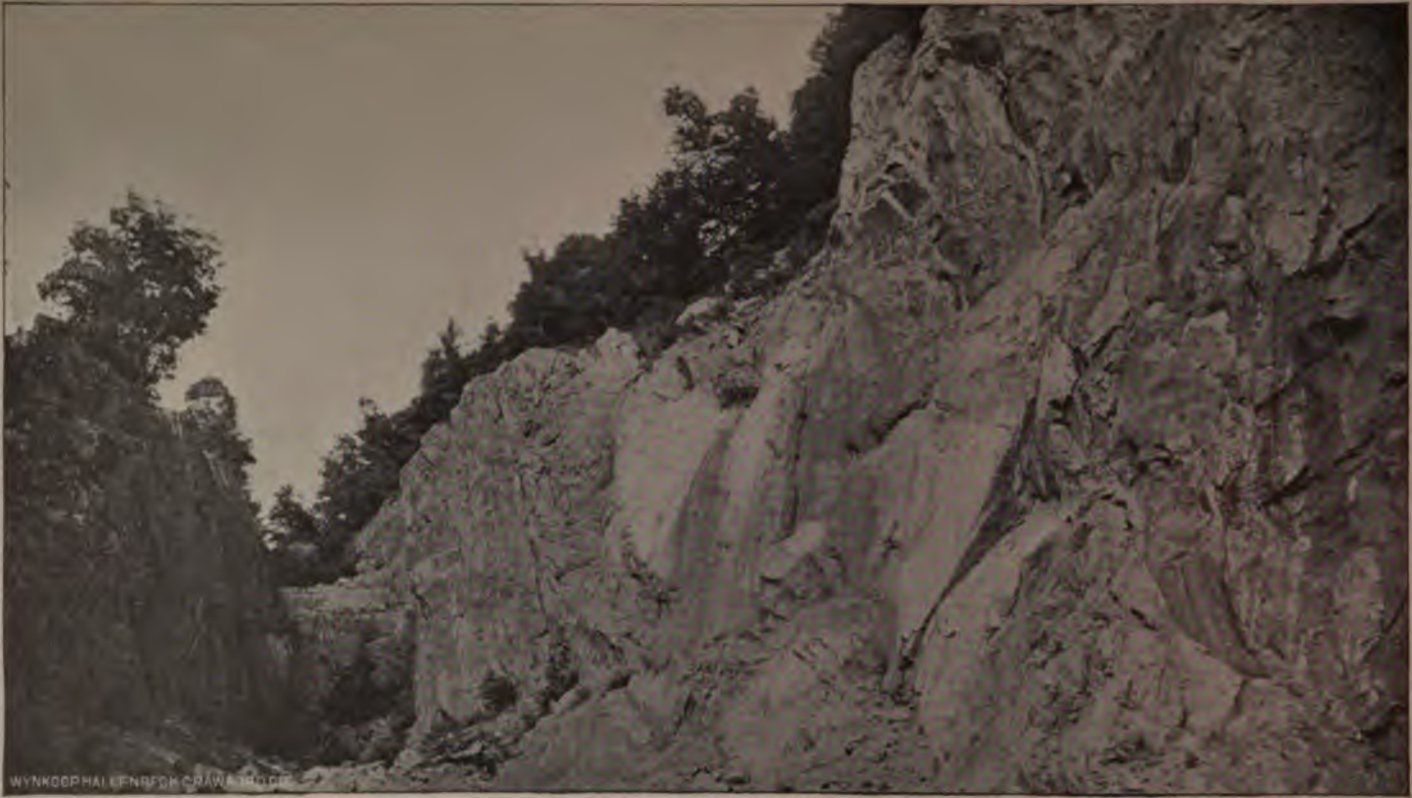
—— Geologic relations from Green pond, N. J., to Skunnemunk mountain, N. Y. (*see* Bul. 5. Geol. soc. Am. p. 367)

Dwight, W. B. Calciferous as well as Trenton fossils in the Wappinger limestone at Rochdale and a Trenton locality at Newburgh, N. Y. (*see* Am. jour. sci. 1880. 19: 50)

Kemp, J. F. & Hollick, A. The granites at Mounts Adam and Eve. (*see* Annals N. Y. acad. sci. 7: 638)

Ries, Heinrich. Report on the geology of Orange county. (*see* 15th an. rep't N. Y. state geol. p. 393)

Mather, W. W. Geol. 1st dist. N. Y. 1843.



Limestone quarry at Arden

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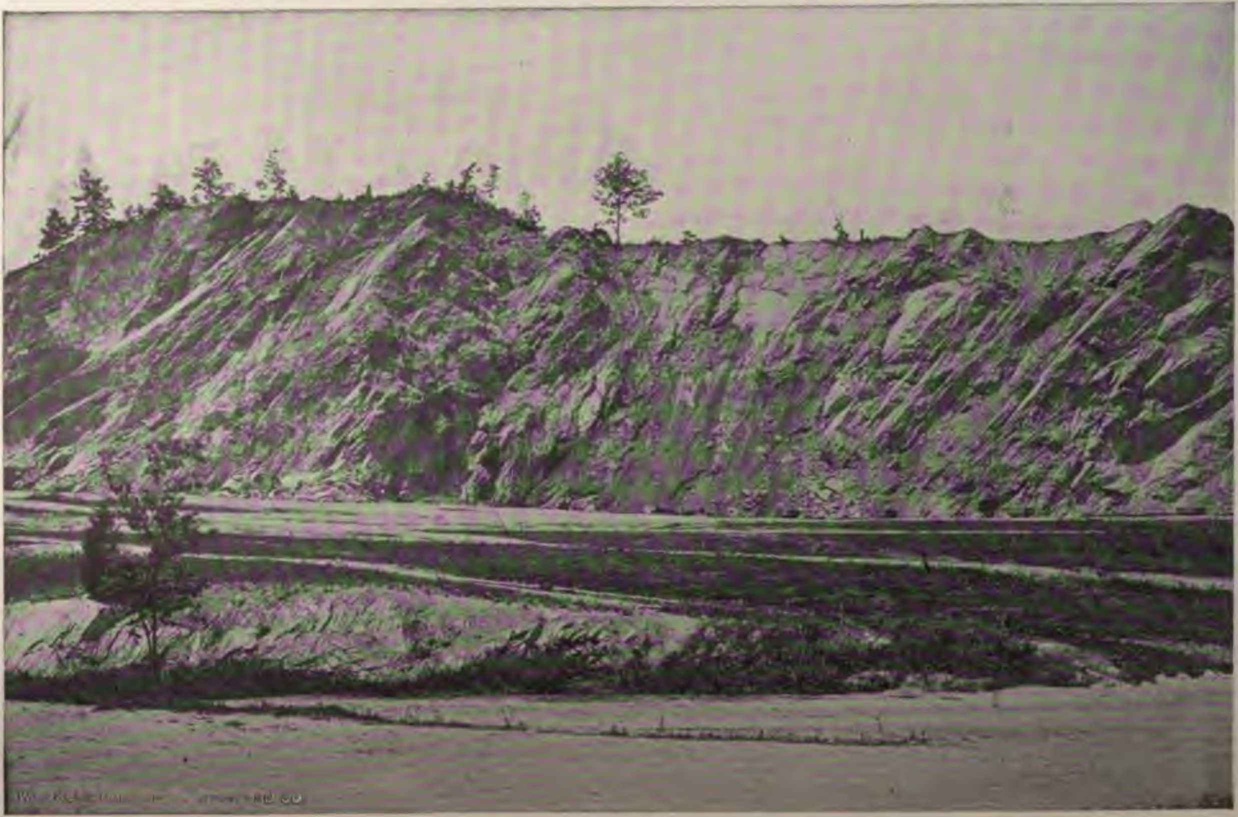
Plate 58 To face p. 809



H. Ries, photo. Limestone quarry, Tomkins Cove, Rockland co. Metamorphosed Calciferous limestone layers in the same quarry, one perhaps containing only 2%, while the others may have 15% or 18%.

An area of white limestone extends from Florida through Pine Island and Amity into New Jersey. This is a highly crystalline, metamorphosed limestone, which also occurs in a broad belt that extends southwest from Florida through Big Island and Gardinerville into New Jersey. It possesses the same character as the other belt. A small area of Trenton limestone is found along the railroad between Neelytown and Campbell Hall. This has been used to a small extent for lime. The Cambro-Silurian limestones also outcrop both southwest, west and north of the city of Newburgh.

The character of these Cambro-Silurian rocks of the Orange and Rockland county belt may be judged from the following analyses made of samples collected from different parts of the quarry, the analyses in each case representing the average of the quarry.

The first one of the magnesian limestone from Tompkins Cove, (pl. 58) is as follows:

Lime	26.34
Magnesia	16.74
Carbonic acid	39.1
Alumina	4.13
Ferric oxid	1.05
Silica	12
	99.36

This analysis shows that the stone is both magnesian and highly silicious. The following analysis of the Cambro-Silurian limestone from Miller Bros.' quarry on the southwestern edge of Newburgh indicates the rather constant character of the stone. It runs:

Lime	27.75
Magnesia	17.65

Carbonic acid	40.99
Alumina	1.93
Ferric oxid	1.8
Silica	10.46
	100.58

This stone is used to a small degree for lime-making.

While swampy tracts are abundant in Orange county, the writer has not been able to prove the existence of marl under any of them.

The Lower Helderberg limestones, though known to occur along Schunemunk mountain in the eastern part of Orange county, are not important there, but do form a prominent strip along the western side of Shawangunk mountain. The Pentamerus is exposed in a quarry about 4 miles southwest of Otisville and was at one time burned for lime (pl. 59). A much better section is exposed in Bennett's quarry east of Port Jervis, and adjoining the road to Middletown at a point about 1 mile east of TriStates. This stone would be available for Portland cement manufacture.

The Corniferous or Upper Helderberg forms a low ridge east of Port Jervis, and also underlies TriStates point. It is full of chert nodules.

Orleans county[1]

This county, like several of the others bordering on Lake Ontario, contains a broad band of the Niagara limestones. The material utilized in every case for the manufacture of lime is the upper member. Quarries are in operation at Barre Center, south of Albion, (pl. 60) Clarendon and Shelby.

At the first named locality, the material used is chiefly disintegrated surface blocks. At this point one of the quarrymen, B. Johnson, recognizes three types of stone, viz, the porous, or

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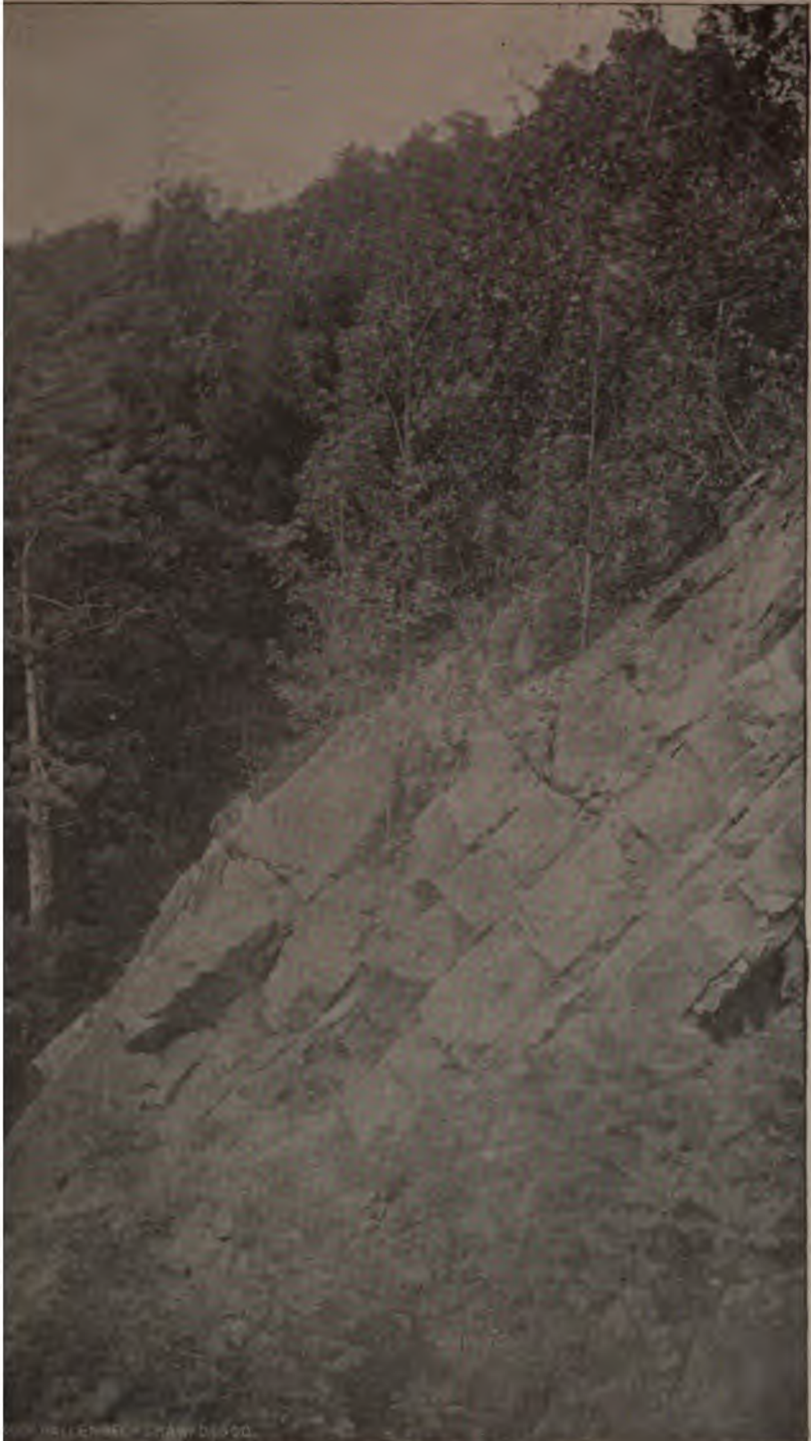
[1] Hall, James. Geol. 4th dist. N. Y. p. 433.

Plate 59 To face p. 810



Quarry in Pentamerus limestone, southwest of Otisville

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H. Ries, photo.

Field south of Albion, where Guelph boulders are quarried for lime

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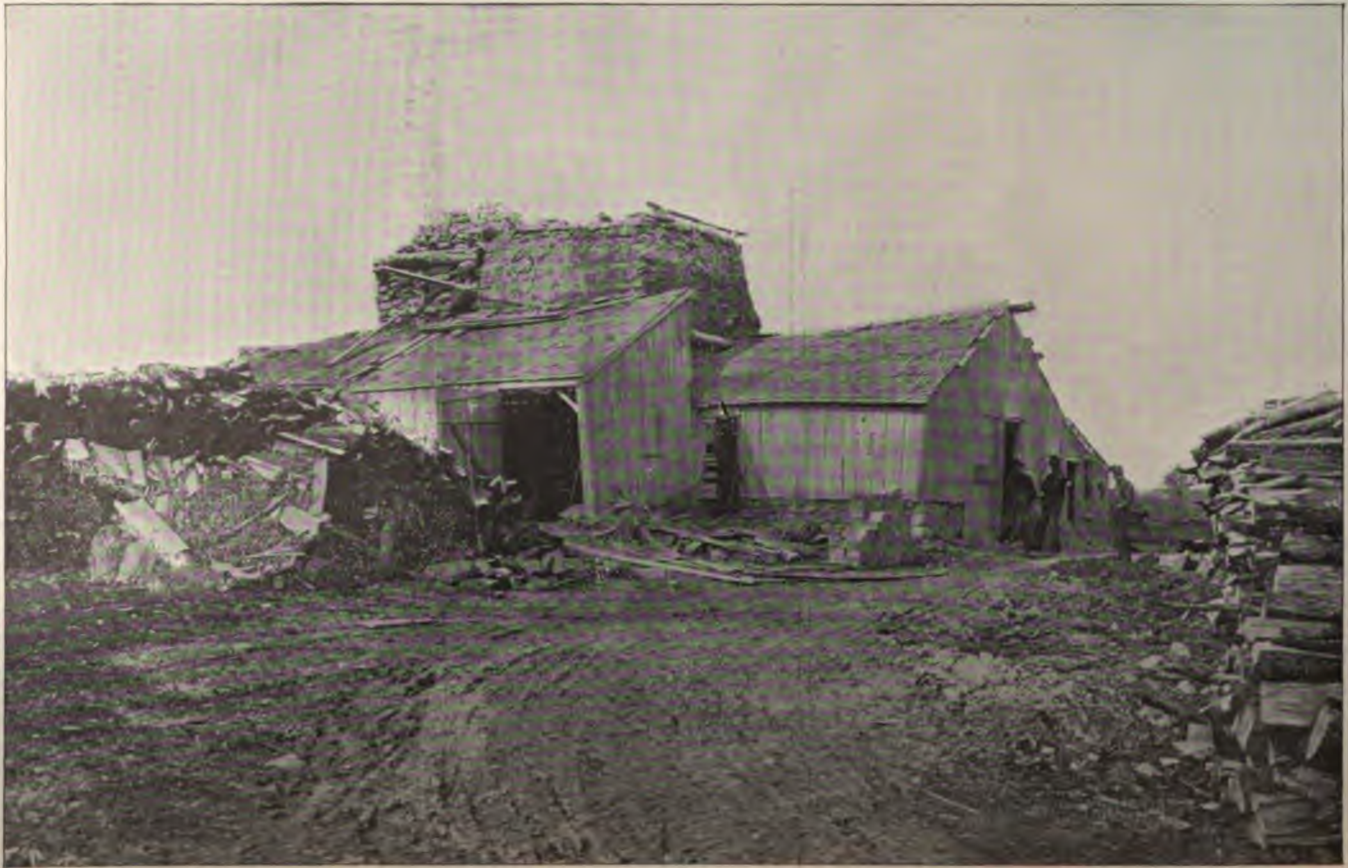
Plate 61

To face p. 811



H. Ries, photo.

Johnson lime kiln, Barre Center

second grade rock, the massive, or first grade, and a third type of more earthy appearance, which slakes very readily when burned. The product from Johnson's (pl. 61) and also T. F. Staine's kiln is sent largely to Batavia.

Extensive deposits of marl occur near Clarendon, southwest of Holly, but the material is not worked. Marl is said to be found 2½ miles north of Medina,[1] and southwest of Clarendon. Some effort has been made to employ it for Portland cement.

Putnam county[2]

Quarries exist at Patterson and at Towners in Putnam county. The quarry at Towners is 1 mile northwest of the New England railroad. The stone is gray and white, coarsely crystalline and contains many crystals of white or light green pyroxene scattered through it. Mica flakes are also abundant in the rock. It is a magnesian limestone with considerable silica in its composition. The quarry at Patterson is on the Haight property half a mile southeast of the railway depot. The opening is about 15 by 40 feet in area and 60 feet deep. A number of blocks of stone have been taken out, but all show the rock to be full of mineral impurities, such that it would not make a very high grade lime.

Rensselaer county[2]

A belt of impure limestone of Cambro-Silurian age extends from Lebanon Springs to Petersburg, but outcrops are scarce.

Another small area extends from the vicinity of North Petersburg to Eagle Bridge and underlying an area several miles wide west of Hoosick Falls. At the last locality a number of small quarries have been opened on a hill west of the town, and show well the varying character of the stone, as well as its purity in certain beds. The rock varies from a nearly pure limestone to a black calcareous slate. It has been used to some extent for flux in a local furnace, while some has been shipped to Troy, and at times it has also been used for lime manufacture.

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[1] Hall, James. Geol. 4th dist. N. Y. p. 437.
[2] Mather, W. W. Geol. 1st dist. N. Y. 1843.

The best stone is found in Cornelius McCaffery's quarry. The section there is nearly 60 feet thick, rather flinty in the upper part but in the lower yielding stone which analyzed:

Silica	1.2
Ferric oxid	1.5
Alumina	2
Lime	34.11
Magnesia	8.97

St L[illegible] [illegible]ounty[1]

The Trenton-Chazy lim[illegible] [illegible]extend along the St Lawrence river from Chippewa Bay to the [illegible]heastern edge of the county. Their southeastern boundary passes [illegible]hrough Flackville, Norwood, North Stockholm, Brasher Falls and Fort Covington Center.

At Ogdensburg the stone has been quarried for lime manufacture about a mile west of the town. The stone is thin bedded, and only the upper layers of the quarry are used for lime.

The following analyses show not only the dolomitic character of the rock but also the greater freedom from silica of the upper layers.

Upper stone, Howard's quarry, Ogdensburg:

Silica	4.42
Alumina	2.23
Ferric oxid	.16
Lime carbonate	55.87
Magnesium carbonate	37.74
	100.42

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[1] Smyth, C. H. jr. A geological reconnaissance in the vicinity of Gouverneur, N. Y. (*see* Trans. N. Y. acad. sci. 12: 97)

—— Preliminary examination of the general and economic geology of four townships in St Lawrence and Jefferson counties, N. Y. (*see* 47th an. rep't N. Y. state mus. p. 687)

Lower stone, Howard's quarry, Ogdensburg:

Silica	17.28
Alumina	5.21
Ferric oxid	.92
Lime carbonate	58.17
Magnesium carbonate	18.46
	100.04

The crystalline limestones form a belt many square miles in extent, stretching in a northeast and southwest direction; in addition there are small scattered patches, which are irregularly distributed throughout the county. According to Smyth the largest limestone belt is that which is traversed longitudinally by the Rome, Watertown and Ogdensburg railroad, and extends from Antwerp to a point 2 miles east of De Kalb Junction. While it is thus seen that the limestone underlies a considerable area, at the same time, owing to a scarcity of outcrops, its presence is not always noticeable. The linear extent of this belt from Antwerp to its probable end in Canton is 35 miles. Its width in a northwest and southeast direction is variable. It is 2 miles at Antwerp, 6 to 8 at Gouverneur, but then narrows again. The limestone is highly crystalline in character, and varies in color from a white to a dark bluish gray. It is unfortunately often rendered impure more or less by scattered grains or somewhat similar masses of minerals, of which the most important are serpentine and tremolite. In some localities these crystalline limestones reach a high degree of purity. The following two analyses were kindly furnished me by Prof. Priestley, of St Lawrence university. No. 1 is a stone used for lime from a locality on the road to Colton and 6 miles from Canton. No. 2 is from Steven's quarry on Grass river 1 mile above Canton. The second one is not used for lime.

	1	2
Silica	.5	1.12
Iron oxid and alumina	1.3	1.89
Lime carbonate	88.67	76.48
Magnesium carbonate	9.53	19.97
	100	101.11

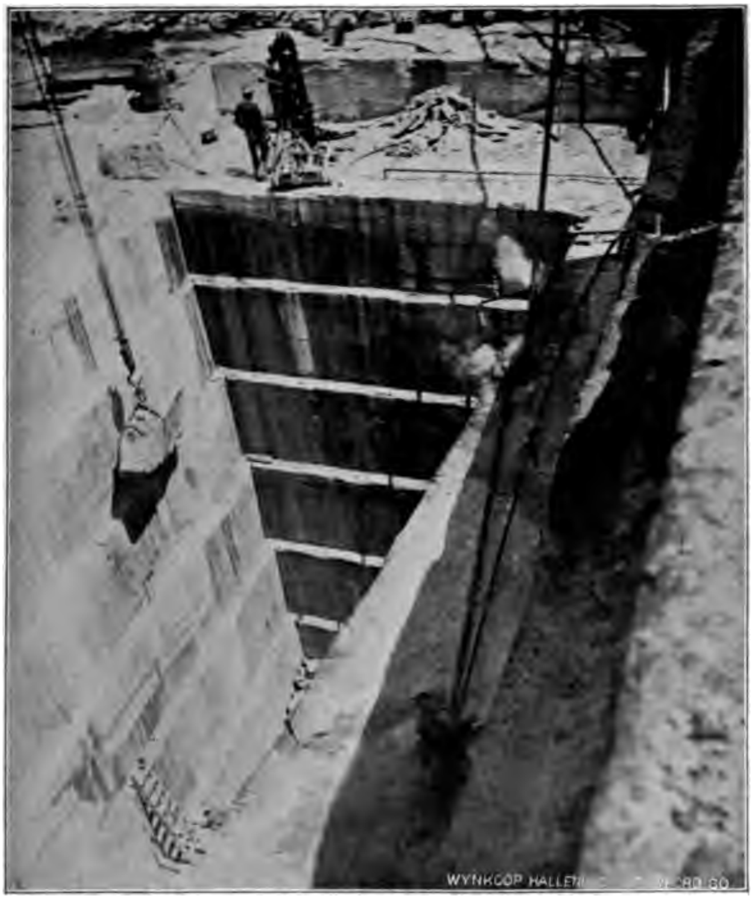
At Gouverneur extensive quarries have been opened for obtaining marble, ar efuse is used for lime. This stone often runs] as indicated by the following analyses made by

Silica	1.85
Alumina	.23
Ferric oxid	.38
Lime carbonate	92.29
Magnesium carbc	4.28
	99.03

The crystalline limestone is well exposed at Harrisville (N. Y.) in the quarries of the Harrisville marble co., which lie about half a mile from the Carthage and Adirondack railroad. The rock there approaches very closely in composition to that at Gouverneur. There is a considerable ledge of crystalline limestone on the Hungerford farm, near Lewisburg, about 4½ miles north of the natural bridge. It is rather far from a railroad, but it has been estimated that it could be put on the car at Natural Bridge for $1.35 a ton. The stone is coarsely granular but not very hard. Certain portions of the rock are very white, evidently quite pure but rather free from silica. Other portions contain an abundance of mica grains.

The following analysis of these white dolomites was made by G. J. Donohue and furnished to the writer by C. Graves of Natural Bridge (N. Y.)

Plate 62 To face p. 814



J. N. Nevius, photo.

Empire marble co.'s quarry near Gouverneur, St Lawrence co. pre-Cambrian

Silica	.24
Ferric oxid alumina	.24
Lime	22.43
Magnesia	29.48
Carbonic acid	47.73
	100.12

In addition to the main belt of crystalline limestone mentioned, there are a number of smaller areas, which are quarried at Bigelow, Brasie Corners, Crary Mills, East Pitcairn, Hickory, and Rossie.

That from Rossie which is quarried by C. Williams & Co. is used by the Dexter sulfite pulp and paper co., which made the following analysis of the lime.

Lime	91.72
Magnesia	7.52
Ferric oxid and alumina	.38
	99.62

Saratoga county[1]

The limestones are mostly Calciferous, though some Trenton occurs. Owing to their irregular distribution and faulted relations, the occurrences can be best determined from the accompanying map. Most of the quarries are located in the Calciferous, but there are also some excellent exposures of Trenton, fully equal to those along the Hudson river at Glens Falls.

The composition of some of the Calciferous beds may be judged from the analysis given below. At Sandyhill, both the Calciferous and Trenton limestone occur. The Calciferous is quarried by Higley, Monty & Co., but, owing to its silicious nature, it has been used only for building stone. It analyzed

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[1] Darton, N. H. Geology of the Mohawk valley, in Herkimer, Fulton, Montgomery and Saratoga counties. (*see* 47th an. rep't N. Y. state mus. p. 603)

—— Preliminary description of the faulted region of Herkimer, Fulton, Montgomery and Saratoga counties. (*see* 14th an. rep't N. Y. state geol. p. 33)

Mather, W. W. Geol. 1st dist. N. Y. 1843.

Lime	29.05
Magnesia	12.8
Ferric oxid	1.02
Alumina	.46
Carbonic acid	38.6
Insoluble residue	18.04

The Trenton limestone is exposed about 1½ miles east of the canal, and the se [illegible] r to that found at Glens Falls, the upper layers [illegible] impure and the lower layers showing 8 feet [illegible] ne evidently of considerable purity.

Other quarries are at [illegible] Springs and South Glens Falls.

[illegible] county[1]

This county is destitute [illegible] stones except a small area of Calciferous in its extreme n[illegible] western corner, and a bit of Lower Helderberg in the southwe[illegible]ern portion. Both are of small extent. Limestone is quarried at Hoffmans.

Schcharie county[2]

This county exhibits a great thickness of Helderberg limestones, which have been opened up at Schoharie, Howe Cave, Barnerville, Cobleskill, Middleburg, Sharon Center, Sharon Springs and Cherry Valley. The general section can be obtained from the account of the Helderberg limestone formation in another portion of the report.

At both Schoharie and Howe Cave there is a splendid development of the lower Pentamerus and Tentaculite members. The former beds, which are 60 to 70 feet thick, are hard, massively bedded, vertically jointed limestones, of bluish gray color.

The Tentaculite beds, underlying the Pentamerus, are thin bedded, dark blue limestones, whose layers vary from 2 to 3 inches. At Howe Cave and Schoharie their thickness is 40 feet.

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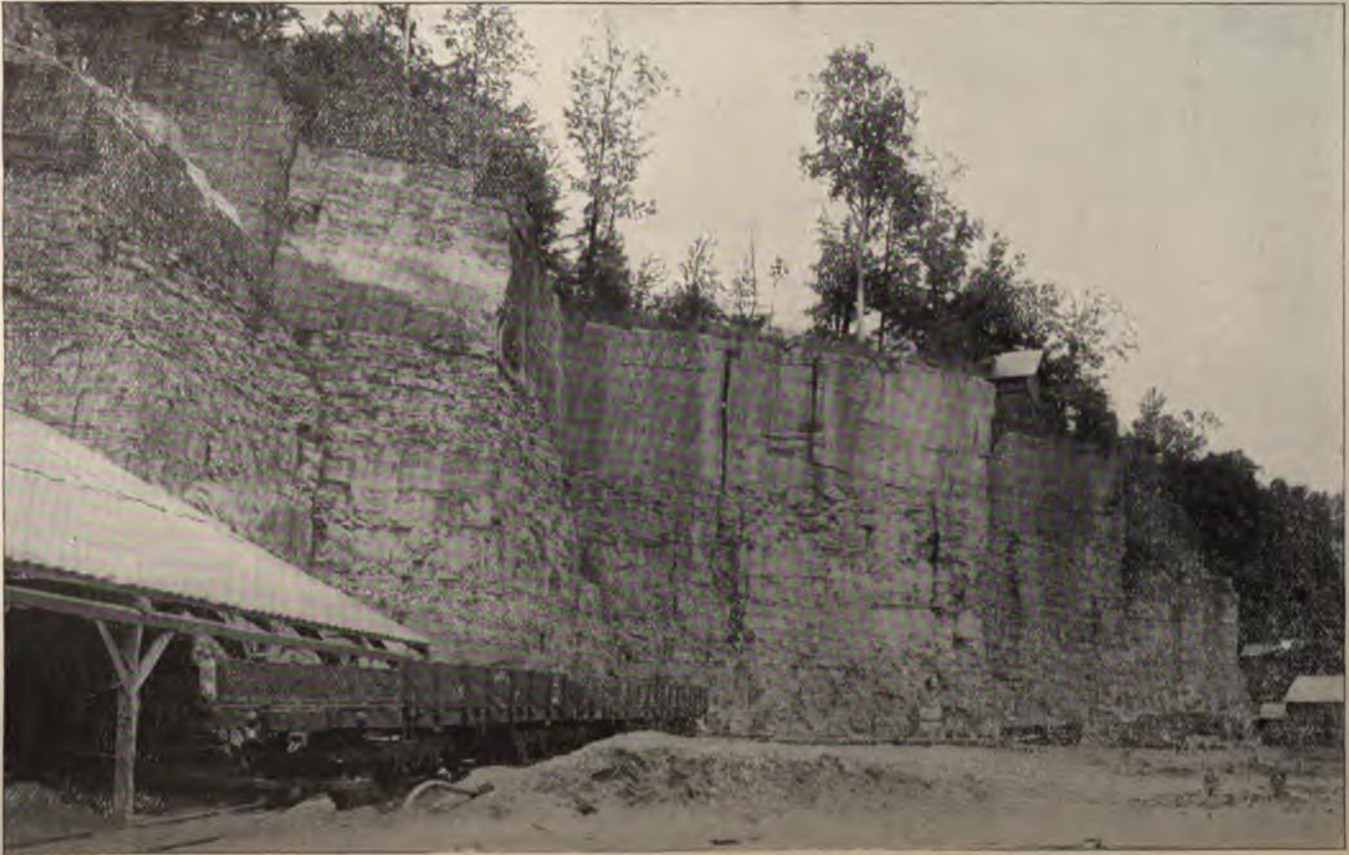
[1] Vanuxem, Lardner. Geol. 3d dist. N. Y. 1842.
[2] Mather, W. W. Geol. 1st dist. N. Y. 1843.

Plate 63

To face p. 817



H. Ries, photo.

Quarry of Helderberg cement co. at Howe Cave

In the quarries of the Helderberg cement co. (pl. 63) at Howe Cave, 120 feet of the two limestones just mentioned is exposed. They are used for the manufacture of Portland cement, being mixed with clay. Underlying the limestone is a bed of natural rock cement, which is also utilized. The following analyses were furnished by C. R. Ramsey, superintendent of the works.

	Gray stone	Blue limestone	Clay
Lime	52.18	52.58	2.9
Magnesia	1.27	.79	.....
Silica	2.7	3.12	71.67
Alumina and ferric oxid	1.64	.93	15.08
Sulfur	.17	.24	.....
Ignition	15.13	18.8	5

The first two analyses are not very consistent; for it is hard to conceive how a stone containing 52.18% of lime could yield only 15.13% on ignition.

The cement rock is said to yield on analysis:

Lime carbonate	55.17
Magnesium carbonate	19.71
Silica	12.89
Ferric oxid and alumina	11.15
Water	.66

Another analysis of Howe Cave limestone, made by C. A. Schaffer,[1] gave:

Lime carbonate	97.24
Magnesium carbonate	1.39
Ferric oxid and alumina	.73
Silica	1.27
Sulfur	tr.
Phosphoric acid	none
	100.63

---

[1] 20th rep't U. S. geol. sur. pt 6, p. 428.

At Barnerville, between Howe Cave and Cobleskill, a very large quarry has been opened in the same limestone, for building purposes (pl. 64, 65). The stone is said to yield on analysis:

Lime	51.05
Magnesia	1.65
Silica	4.31
Alumina and ferric oxid	.97
Sulfur	.29
Carbon dioxid	41.9
	100.17

Schuyler county[1]

South of Alpine station on the Lehigh Valley railroad is a large tamarack swamp, whose surface is underlain by from 3–8 feet of muck. Below this is found a deposit of marl which varies in thickness from 2–10 feet, being as much as the latter in many spots.

The property is owned by J. Hinman.

Seneca county[2]

The Upper Helderberg formation covers a belt widening westward, which extends from opposite Union Springs on Cayuga lake westward toward Geneva on the south and Thornton Corners on the north. It is quarried at both Seneca Falls and Waterloo, the quarries being mostly in the Seneca beds, but partly in Corniferous. At Seneca Falls the quarry is operated by G. J. Fisher, and at Waterloo the quarry operators are D. Babcock, Edson Bros., G. C. Thomas & Bros., B. Frank. The following section is from Babcock's quarry (pl. 66). Beginning at the top there is:

Dark, fine grained limestone	0′	14″
Cherty limestone	6′	0″
Cherty limestone	2′	0″
Shale.	0′	10″
Two 17 inch layers, fine grained limestone,	2′	10″

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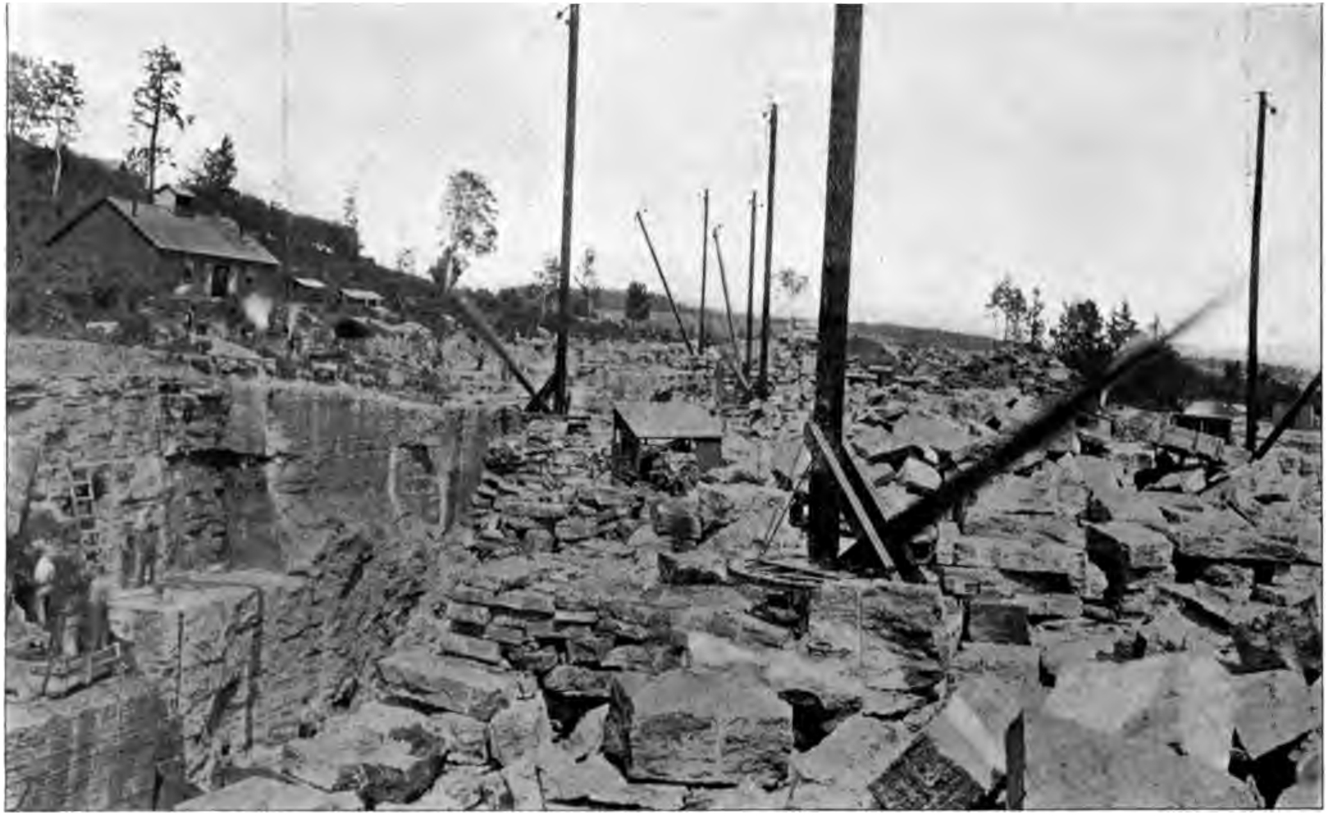
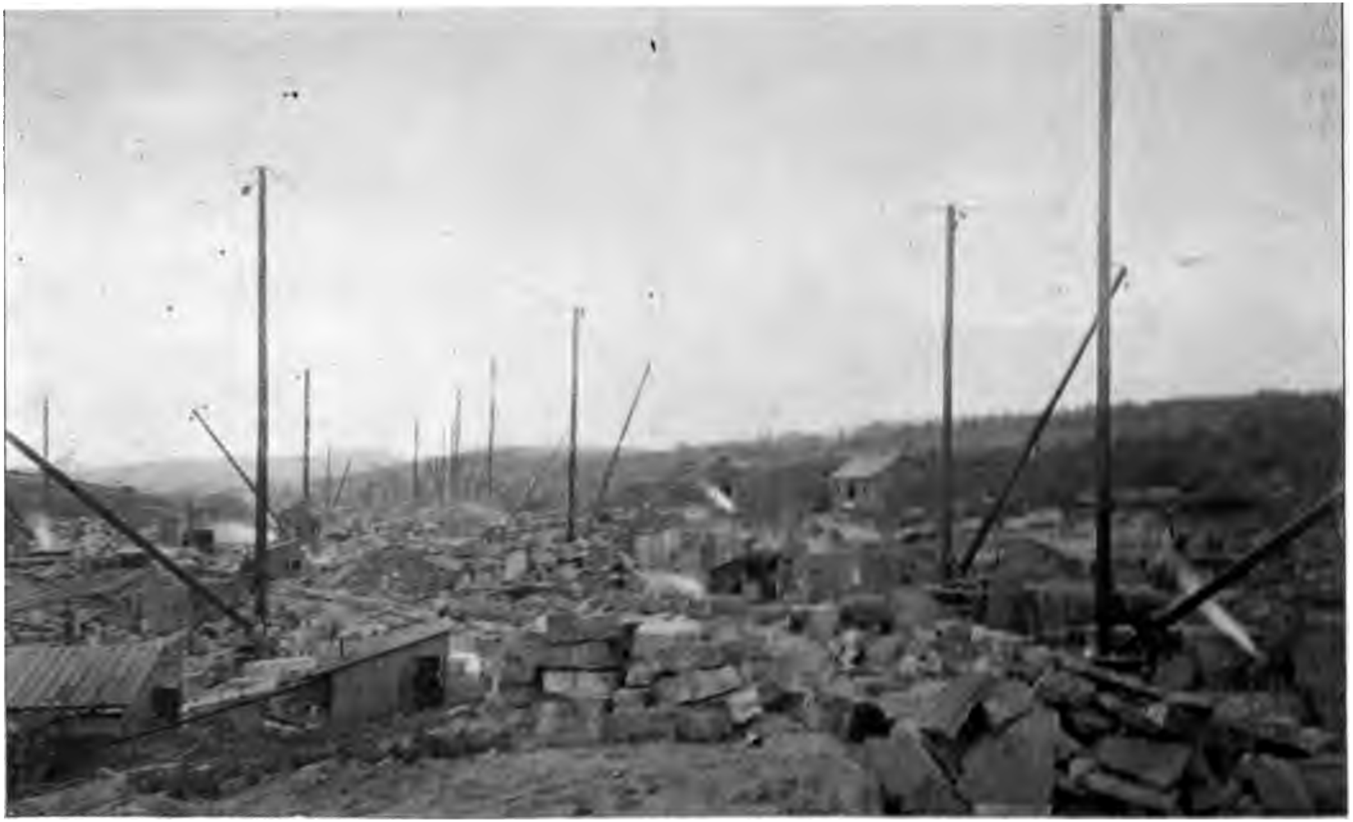
[1] Hall, James. Geol. 4th dist. N. Y. p. 449.

Lincoln, D. F. Geology of Seneca county. (*see* 15th an. rep't N. Y. state geol. p. 57)



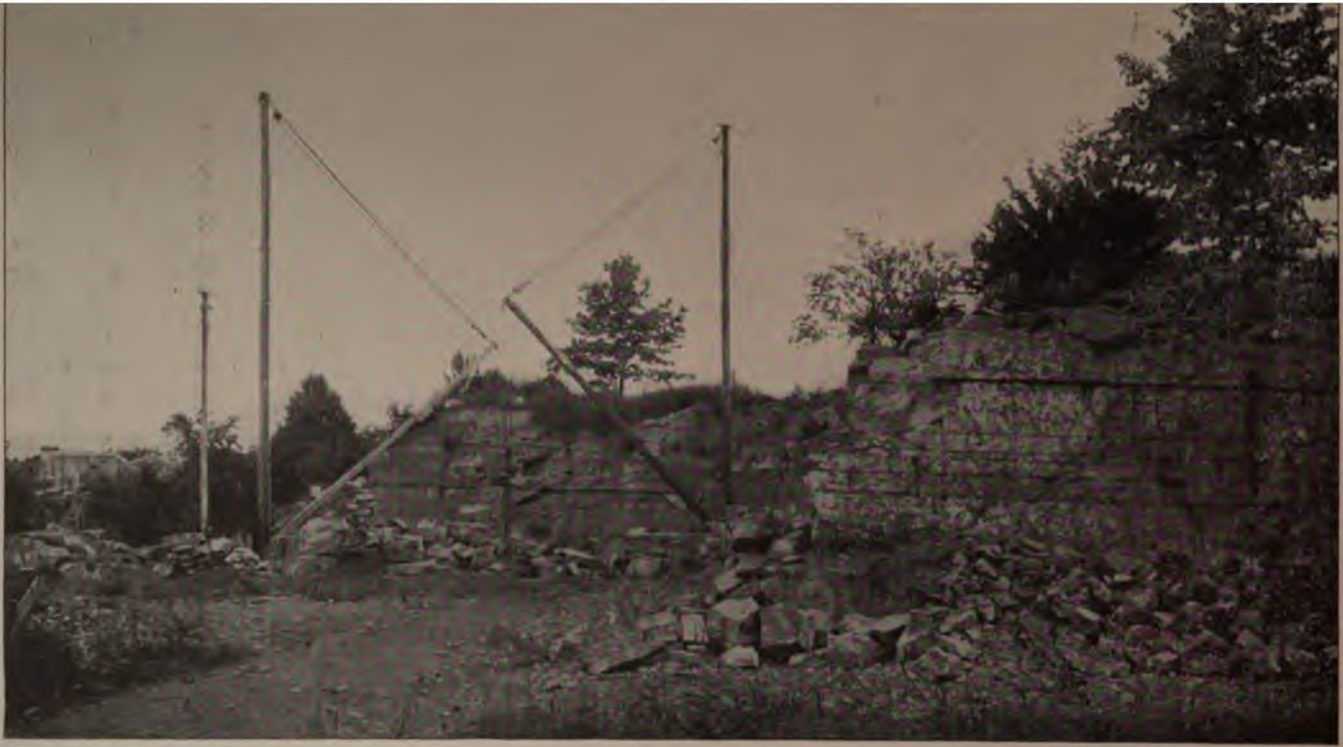
H. Ries, photo.

Quarry at Barnerville, near Howe Cave



H. Ries, photo.

Quarry at Mellenville, near Stone Cave



H. Ries, photo.

View of Babcock's limestone quarry, Waterloo

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ASTOR, LENOX AND
TILDEN FOUNDATIONS

Plate 67

To face p. 819

Valley at Perkinsville, underlain with marl

The 14 and 17 inch layers make good lime and are shipped to Geneva for burning. The average composition of the rock is as follows:

Silica	14.85
Alumina	7.18
Ferric oxid	1.57
Lime	40.23
Magnesia	1.95
Carbon dioxid	33.76
	99.54

The Tully limestone lies between the Hamilton and Genesee shales, and is of importance, as it is the most southern lime rock of central New York. It outcrops at several localities according to D. F. Lincoln.[1]

The most northern is about a mile west of Hayt Corners; a second exposure is at Willard hospital, where it forms the cascades near the reservoir; another on Seneca lake 1 mile south of Willard landing, where 15 to 20 feet is exposed; still other outcrops are in the creek near Highland station and at Lodi.

A quarry has been opened in it 1 mile southeast of Hayt Corners.

Steuben county[2]

No beds of limestone are found within the county, but an extensive deposit of marl is dug at Perkinsville and Wayland (pl. 67). It lies in a great swampy area, and furnishes material for two Portland cement works, that of Millen & Co., of Wayland, and the Wayland Portland cement co., located at Perkinsville. Though the deposit is of considerable extent, it is not underlain by clay, which has to be brought from Morrisville.

Tompkins county[3]

The only limestone formation is the Tully, which outcrops on the eastern shore of Cayuga lake between Lakeridge and Lansing along the Auburn branch of the Lehigh Valley railroad.

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[1] Lincoln, D. F. Geology of Seneca county. (*see* 15th an. rep't N. Y. state geol. p. 57)

[2] Hall, James. Geol. 4th dist. N. Y. p. 480.

[3] Hall, James. Geol. 4th dist. N. Y. p. 475.

The ledges are most prominent at the track level about ¾ mile south of Lansing. The stone is fine grained, moderately hard, and shows occasional impure layers, but comparatively few chert nodules, the impurities being mostly iron and clay. It is a massive rock, with layers 2 to 3 feet thick, the total thickness being about 20 feet, and is favorably situated for either rail or water shipment.

An analysis made of samples taken by the writer from the ledge south of Lansing showed:

Silica	5.7
Alumina Ferric oxid	2.1
Lime carbonate	88.5
Magnesium carbonate	1.4
Insoluble	8.8

Ulster county[1]

The limestone formations occurring in Ulster county together with their thickness are as follows:

	Feet	
Onondaga	60	Cherty
Upper shaly limestone	30–125	Impure
Becraft limestone	20–30	Fairly pure
Lower shaly limestone	60	Impure
Pentamerus limestone	30–60	Dark massive
Tentaculite limestone	20–40	Thin bedded
Cement series	20–50	Cement and waterlime
Niagara limestone	0–45	
Wappinger limestone	200	Silicious

---

[1] Darton. Geology of Ulster county. (*see* 13th an. rep't N. Y. state geol. p. 297).

Dale, T. N. The fault at Rondout. (*see* Am. jour. sci. 1879. 18: 293)

Davis, W. M. The little mountain east of the Catskill. (*see* Appalachia, 3: 20)

———. Non-conformity at Rondout N. Y. (*see* Am. jour. sci. 1883. 26: 389)

———. Becraft mountain. (*see* Am. jour. sci. 1883. 26: 381)

———. The folded Helderberg limestones. (*see* Bul. Mus. comp. zool. Harvard col. 7: 811)

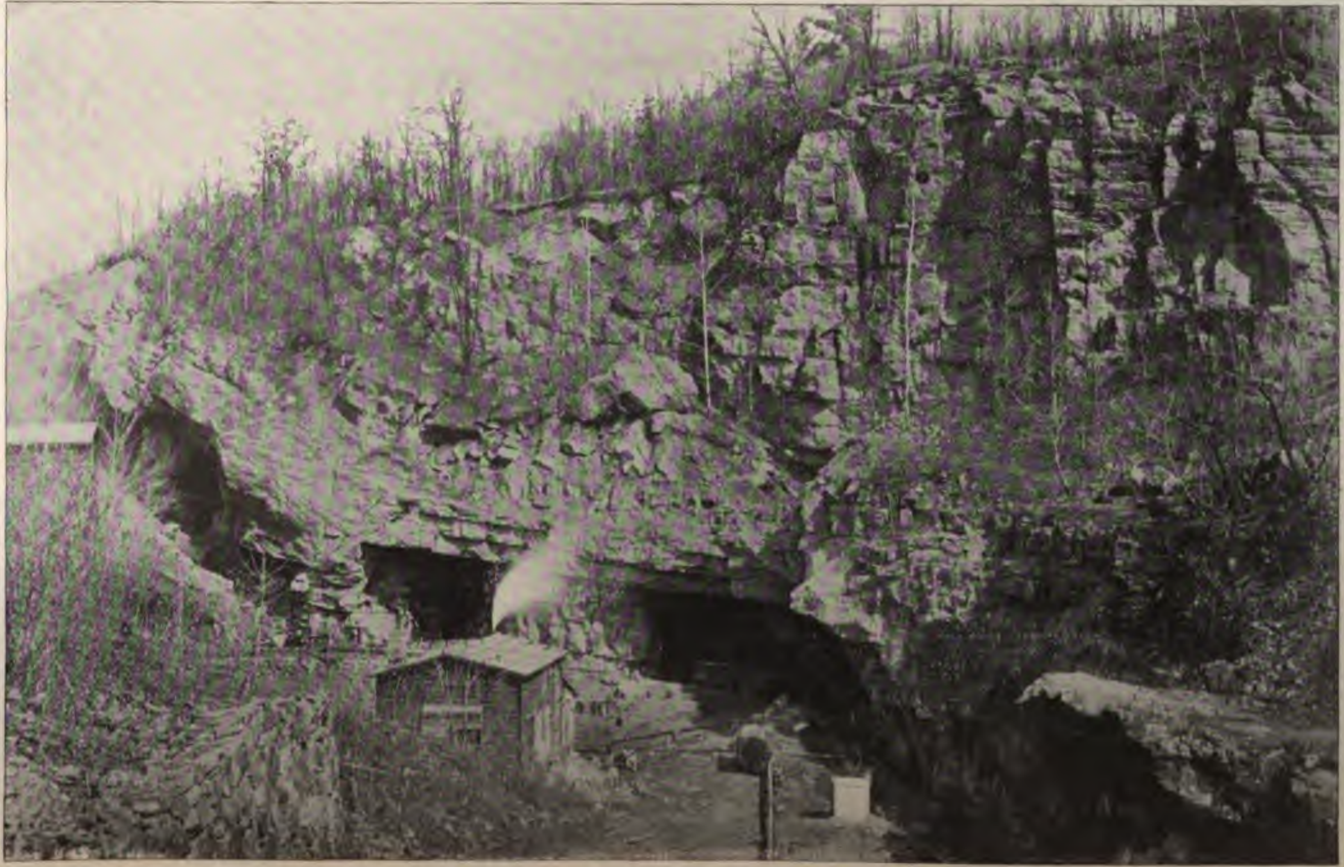
Lindsley. Geology of the cement quarries. (*see* Poughkeepsie soc. nat. sci. 11: 44)

Nason, F. L. Economic geology of Ulster county. (*see* 13th an. rep't N. Y. state geol.)

Mather, W. W. Geol. 1st dist. N. Y. 1843.

Plate 68

To face p. 821

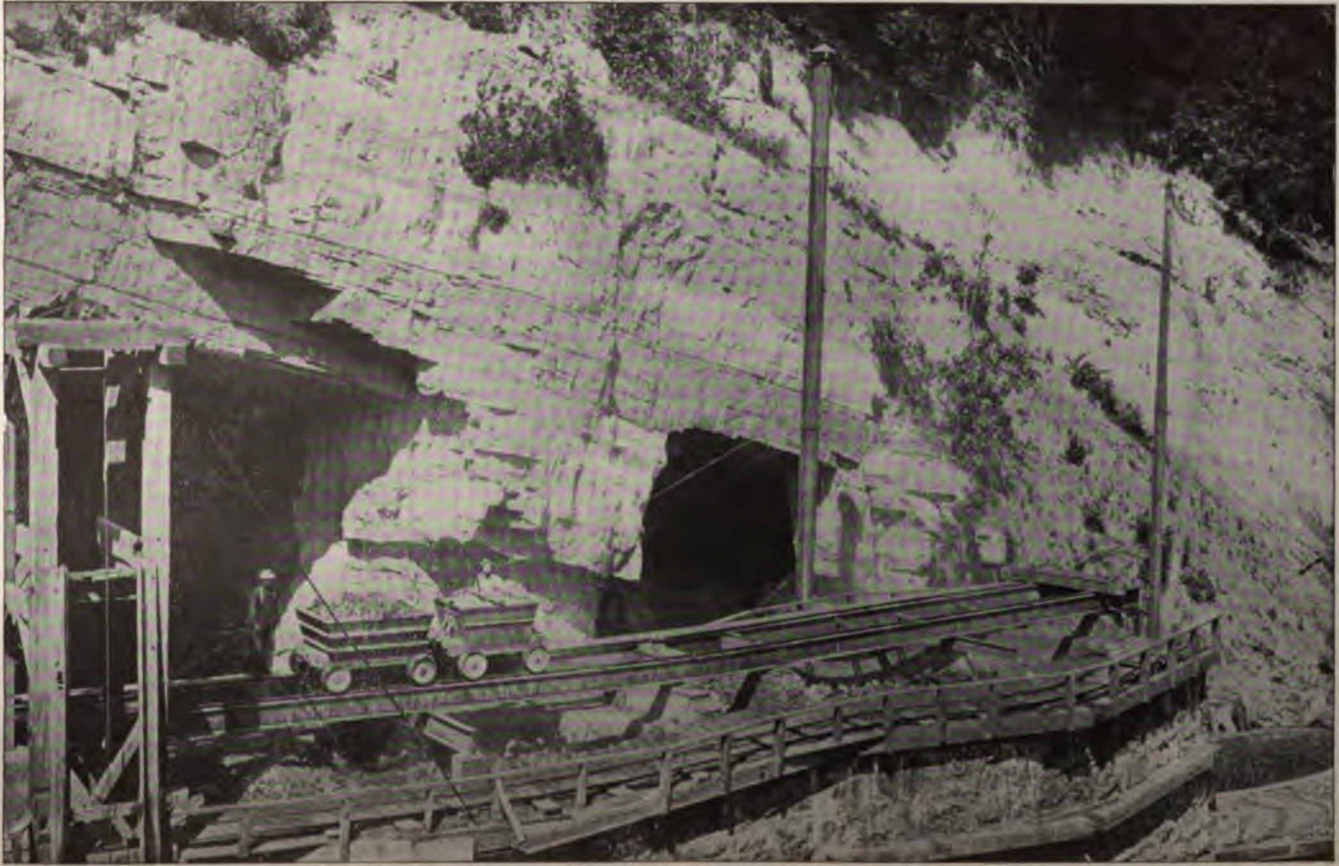


H. Ries, photo.

Quarry N. Y. cement co., Rosendale

Plate 69

To face p. 821



H. Ries, photo.

East end of quarry at Rosendale

Of these the Becraft and the cement beds are the most important.

Onondaga limestone has been quarried at a number of localities for burning into lime. The stone is generally light blue gray, dense and massive. Unfortunately a common feature is the presence of layers of chert, though these may be locally absent. They predominate chiefly in the upper beds.

Darton states[1] that the outcrop of the Onondaga limestone is practically continuous from the northeastern corner of the county to Wawarsing township. Around Kingston its area widens greatly, on account of the presence of folds, and most of the upper part of the city is built on it. Southward by Hurley and Marbletown the Onondaga formation is prominent in the ridge sloping westward to Esopus creek. Exposures also abound along the West Shore railroad northward from Kingston, and, from west of Saugerties to Asbury, along and near the road passing through Cedar Grove and Katsbaan.

Through its whole extent the upper shaly limestone exhibits a large amount of argillaceous and silicious impurities. The beds are massive, but the rocks possess a slaty cleavage, and these properties aid in the formation by them of small rough ridges. It extends across the county parallel with the Onondaga limestone. As far as known, it is not available for any of the uses treated of in this report. The upper shaly overlies the Becraft limestone.

In Ulster county the Becraft is the purest limestone of the whole Lower Helderberg series. The beds are massive, bluish gray to reddish limestone, of a semicrystalline nature and highly fossiliferous. Scattered through the rock are saucer-shaped masses of white, crystallized lime carbonate, from 1 to 2 inches in diameter and representing the bases of crinoid heads. The formation according to Darton varies from 20 to 30 feet in thickness.

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[1] Geology of Ulster county. (*see* 13th an. rep't N. Y. state geol. p. 301)

Extensive quarries have been opened in it near Rondout, Eddyville and Whiteport. The lime made from it is of good quality, lumpy but slightly brown in color. The Becraft limestone extends across the eastern portion of the county from north to south. It is well exposed between Saugerties and Rondout and about Wilbur and Whiteport, but exposures of it are rare southwest of this latter locality except at Mill Hook and Highfalls.

Samples for analysis were collected from the quarry of the Newark ceme [illegible] nd the average of these gave:

Silica	3.87
Ferric ox	1.34
Alumina	1.07
Lime	54.11
Magnesia	tr.
Carbon dio	40.6
	100.99

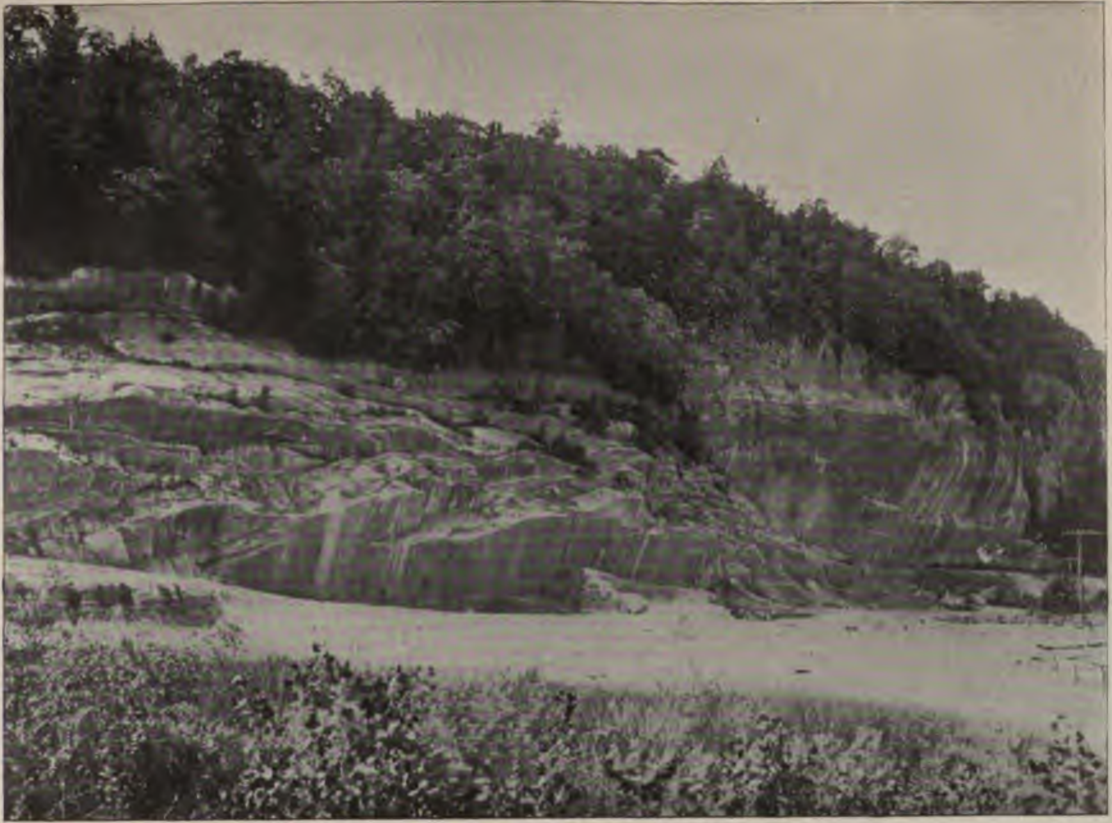
Another set of samp [illegible] he quarry of B. Turner near Wilbur gave:

Silica	7.1
Alumina	2.5
Ferric oxid	1.65
Lime	45.22
Magnesia	tr.
Carbon dioxid	39.1
	95.57

The Pentamerus limestone member of the Lower Helderberg in Ulster county, is a hard, dark blue or lead colored, massive limestone. Not infrequently it is somewhat cherty. Its hard and tough character frequently causes it to give rise to cliffs. Good exposures of this rock occur in the cliffs at Rosendale, about Port Jackson, near Eddyville and along the eastern face of the

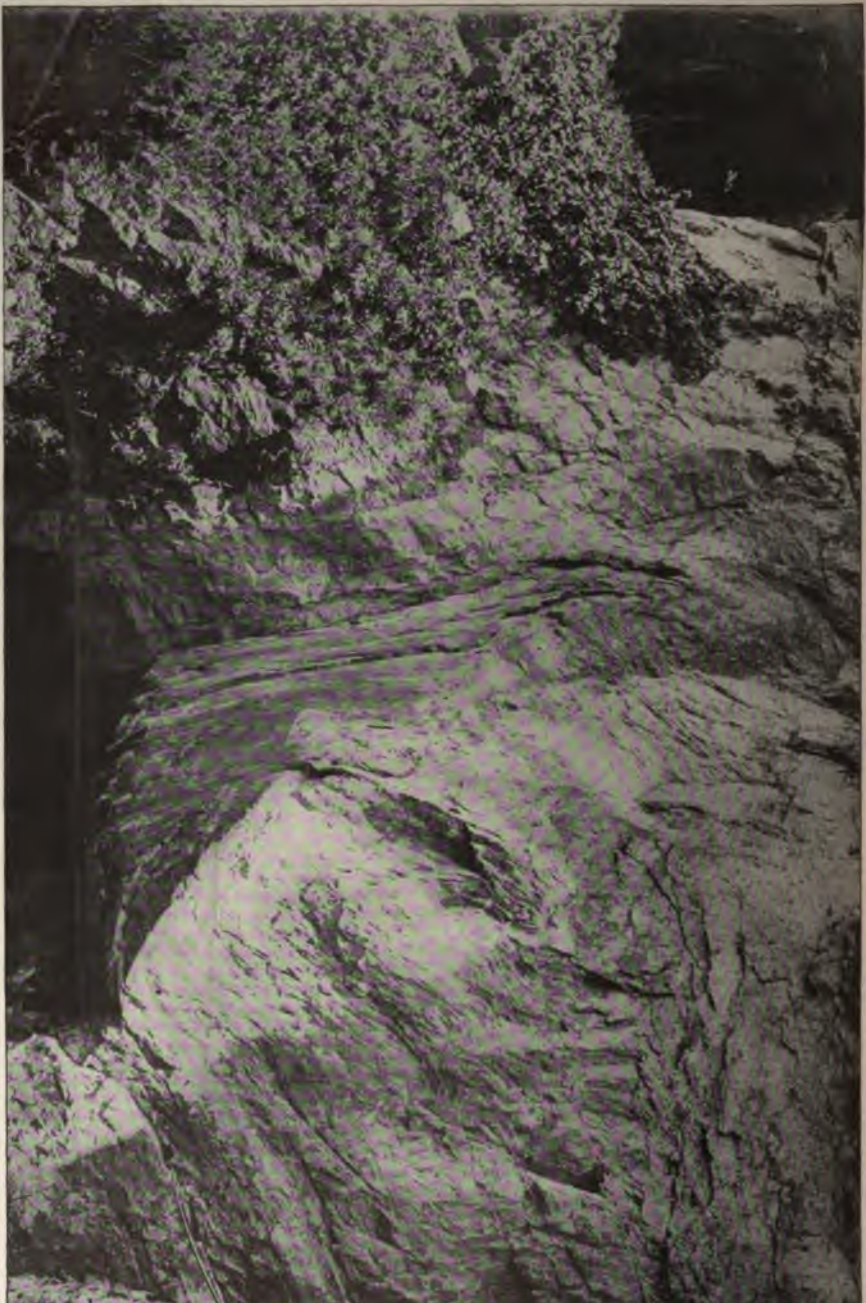
Plate 70

To face p. 822



H. Ries, photo.

Champlain clay resting against glaciated surface, of Helderberg limestone. Terry Bros. brickyard, East Kingston



H. Ries, photo.

Rock at slope of Newark cement co., Rondout limestone ridge extending from Rondout to Saugerties and West Camp. They are generally a mile or more from the shore of the Hudson, but 2 miles north of Rondout approach close to it. The Pentamerus limestone has a thickness of 30 to 40 feet.

Tentaculite limestone is generally a thin bedded, dark blue limestone and forms the base of the Helderberg series. Its thickness varies from 20 to 40 feet and is greatest about Rosendale.

Salina waterlime beds underlie the waterlime and are of considerable importance, as they include the well known cement beds. Darton says: "The usual characters of the formation are thin bedded water limestones, and the cement is of local occurrence." It is a blue black, very fine grained, massively bedded deposit, consisting of calcareous, magnesian and argillaceous materials in somewhat variable proportions.

The cement beds are extensively developed in the Rondout and Rosendale regions. They come in gradually and are attended by a thickening of the formatior from its usual average of 20 to 30 feet to 40 or 50 feet. At Rondout the principal cement bed has a thickness averaging about 20 feet. It lies directly on the coralline (Niagara) limestone and is overlain by altering successions of waterlime and thin. impure cement beds. The cement horizon is not exposed far north of East Kingston, but how far it extends to the northward is not known. It is seen to thicken southward, and it attains its maximum thickness in the vicinity of Rondout, thinning out again and giving place to waterlime beds south of Wilbur. It is seen to have come up again in the Whiteport anticlinal, which brings up a great development of cement beds along its principal axis from Whiteport to Rosendale. They also come out along the western limb of the synclinal eastward. South of Rosendale the cement beds continue up the Coxing kill valley and around the point of the anticlinal by Highfalls on the Rondout creek. "Above this place it can be traced but a short distance, owing to its deep erosion and heavy drift cover in the Rondout creek valley." It reappears at Port Jackson.

are two cement beds in the Whiteport-Rosendale region. The lower one of these averages 21 feet in thickness, and the other averages 12 feet in thickness, with an intervening member of 12 or 15 feet of waterlime beds, but these thicknesses are very variable. At High falls the upper bed is 15 feet thick, the lower bed 5 feet thick with 3 feet of intervening beds of waterlime rock. The High falls are over the thicker beds.

Darton also states that "cement may be looked for in the upper Rondout valley, from Port Jackson to Ellenville, but, owing to the absence of outcrops, this should only be regarded as a suggestion."

Around Rose t industry is developed to an enormous extent, l barrels of cement being produced annually. n of the cement manufacture is made in anothe e eport.

Nothing more i s part of the report concerning the Rosendale ce it is mentioned more fully in the chapter on natural ceme

Coralline or Niagara limest forms a thin bed underlying the cement at Rondout. It is a rk gray limestone of variable thickness. Under the cement at ndout it is 7 feet, but at the entrance to the Becraft limestone quarries 1 mile north of East Kingston it is only 5 inches.

Warren county[1]

Both the Calciferous and Trenton are known in this county. The former is not of very great importance except for building purposes, but the latter is very prominent.

At Glens Falls, the Trenton limestone (pl. 72) has been quarried for a number of years for lime manufacture, and the product bears an excellent reputation. There are four companies operating lime quarries, but the rock in all of them is very much the same. The section in the quarry beginning at the top consists of:

	Feet
Thin bedded, impure black limestone	12-15
Massive black limestone	2- 3
Fine grained, black, crystalline limestone	15

---

[1] Emmons, Ebenezer. Geol. 2d dist. N. Y. 1842. p. 170.

The upper bed is used for building and also for Portland cement, being mixed with the overlying clay; the lower bed makes a high grade of lime. The following analysis represents the composition of the upper stone.

Silica	3.9
Alumina	1.3
Ferric oxid	.....
Lime	52.15
Magnesia	1.58
Sulfuric acid	.3

The composition of the lower bed is as follows:

Silica	1.1
Alumina	.8
Ferric oxid	.5
Lime	53.17
Magnesia	.75
Carbonic oxid (est.)	45.08
	101.4

The rock has to be carted three quarters to one half a mile for shipment, the distance depending on the quarry from which it is taken. The lime produced is soft but quite pure. It is said to slake rather quickly.

The analysis of the lime in the circular of the Associated lime co. is:

Lime	96.46
Magnesia	.64
Ferric oxid and alumina	1.7
Loss on ignition	1.2

An extensive Portland cement plant has been built at this locality and is described in another chapter.

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Magnesia	.64
Ferric oxid and alumina	1.7
Loss on ignition	1.2

An extensive Portland cement plant has been built at this locality and is described in another chapter.

Washington county[1]

The limestone areas of this county, though not extensive, include some of the purest limestones found in the state. One narrow belt extends from Middlefalls to North Argyle, a second begins at Adamsville and extends northward past the eastern edge of Fort Ann and Whitehall to the Vermont boundary. A third area lies on the boundary between New York and Vermont and along the Rutland branch of the Delaware and Hudson railroad. The rock has been extensively quarried at Smiths Basin and west of Fair Haven.

At Smiths Basin the Keenan lime company has several quarries in the ridge to the east of the railroad. The rock is mostly dark gray to bluish black, fine grained and moderately hard. Its massive character has been somewhat destroyed in places by the shearing and folding to which the rock has been subjected, and the upper beds are shaly and silicious, still the lower ones are very pure. The company has four limekilns of continuous type. Much of the rock has also been shipped to Troy both for use as a flux in blast furnaces and also for lime in Bessemer converters.

The following analyses will serve well to show the composition of the stone.

Silica	1.38
Ferric oxid and alumina	.58
Lime	55.26
Magnesia	.72
Phosphorus	.004

An analysis of the lime made by Prof. J. H. Appleton gave:

Moisture and carbon dioxid	2.08
Insoluble	1.06
Ferric oxid and alumina	.58
Lime	95.5
Magnesia	tr.
	99.22

---

[1] Kemp, J. F. & Newland, D. H. Preliminary report on the geology of Washington, Warren and parts of Essex and Hamilton counties. (see 51st an. rep't N. Y. state mus. 2: 499)

Mather, W. W. Geol. 1st dist. N. Y. 1843.

A third, made by the writer, gave:

Silica	.72
Ferric oxid and alumina	1.5
Lime	54.28
Magnesia	.8
Carbon dioxid	44
	101.3

The existence of an extensive clay deposit in the adjoining meadows offers excellent facilities for the establishment of a Portland cement plant.

A second quarry, operated by D. Nichols & Son, lies about 2 miles northeast of the preceding and is of similar purity.

Black Trenton limestone is also mined just west of the state line in Washington county. The quarry is situated along the railroad track between Whitehall and Fair Haven and is operated by George D. Harris under the name of the Arana marble co.

The rock is a dark colored, moderately hard limestone, with very few visible impurities, and in places traversed with enormous streaks of calcite, and at certain portions of the quarry, noticeably at the western end, the quarry assumes a brownish red color. As a whole, it may be said that the stone is very pure, and where shale impurities occur they are generally in the shape of horses which can be easily separated in the mining of the stone. The following analysis indicates very well the high degree of purity of this material.

Silica	.7
Alumina	1
Ferric oxid	.7
Lime	53.9
Magnesia	1.4
Carbon dioxid	42.5
	100.2

iferous is quarried near Whitehall, but is very silicious.

Wayne county[1]

The Ni ara limestone extends through the county from west to east and is quarried at Walworth and Wolcott.

Hall[2] states that marl underlies the Cayuga marshes in the town of Savannah, and is 5 to 6 feet thick. Another bed is located one mile west of Newark, and a thin bed is formed, under Cooper's swamp, in the town of Williamson.

nty[3]

The limestones in ll of the same age, Cambro-Silurian. They exten nty in a northeasterly direction, forming sever lts which either border or underlie the main val most important are those along the line of the d Harlem railroad and the Northern railroad. fo been extensively opened up at Tuckahoe and Ple nt o far as examined contains the better grade of stone. mportant area occurs south of Sing Sing (now Ossining). Other occurrences are near Somers, Amawalk and Hastings.

The limestones in this county are often highly magnesian, coarse to fine grained metamorphosed rocks. At times they are exceptionally free from silica.

There are two important quarries at Ossining, the one belonging to Henry Marks (pl. 73) the other to the Sing Sing lime co. The stone in Mr Marks's quarry is finely granular and slightly grayish in tint, while the best stone in the Sing Sing lime co.'s quarry is white and coarse grained but possesses a high degree of purity.

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[1] Hall, James. (*see* Geol. 4th dist. N. Y. p. 414)

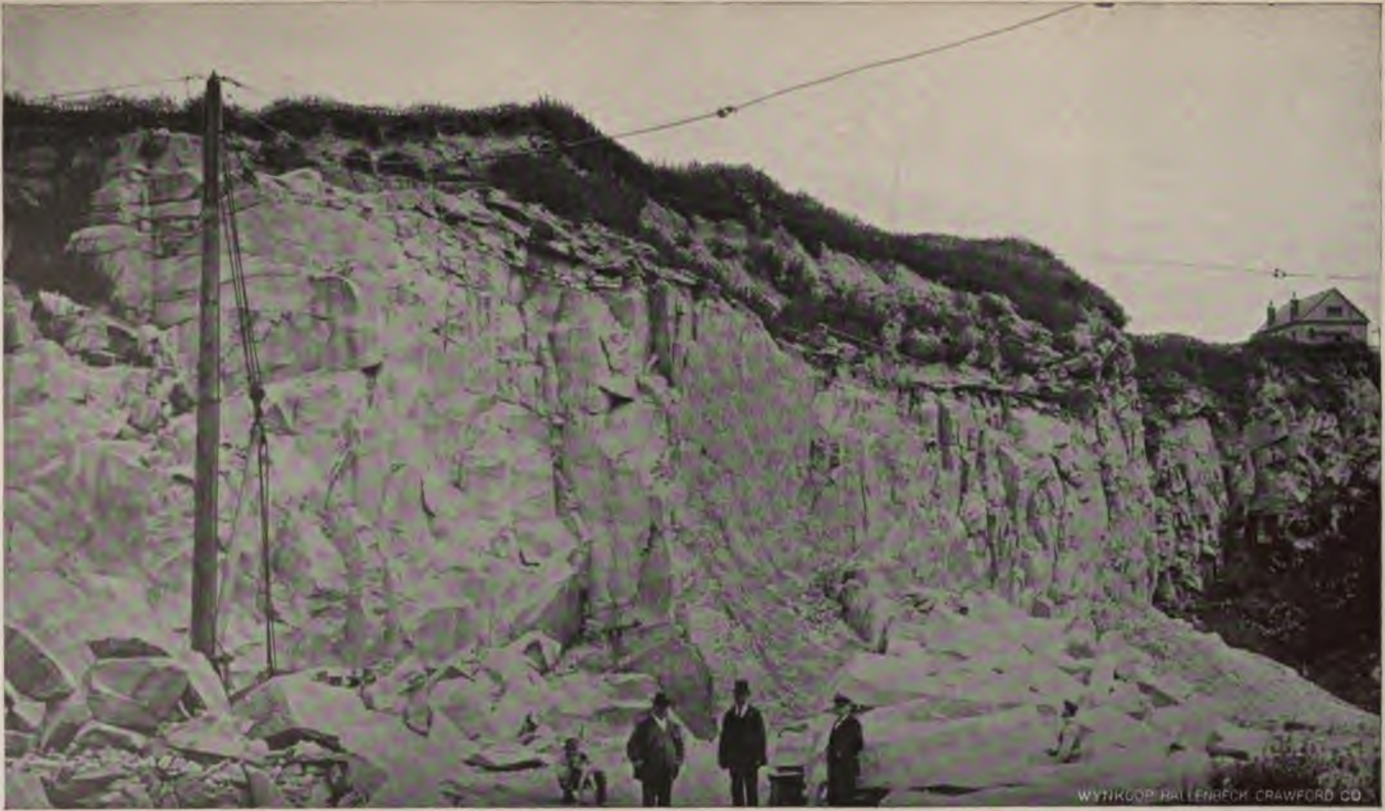
[2] Geol. 4th dist. N. Y. p. 416.

[3] Dana, J. D. Geological relations of the limestone belts of Westchester county, N. Y. (*see* Am. jour. sci. 1880. 20: 21, 194, 359, 450, 456; 21: 425; 22: 103, 313, 327)

Merrill, F. J. H. Geology of crystalline rocks of southeastern New York. (*see* 50th an. rep't N. Y. state mus. 2: 21)

Mather, W. W. Geol. 1st dist. N. Y. 1843.

Plate 73 To face p. 828



H. Ries, photo.

Marble quarry, Ossining, Westchester co. Metamorphosed Calciferous, Trenton limestone

A number of samples were collected from Marks's quarry, and their average composition is as follows.

Silica	.98
Ferric oxid	.3
Alumina	.84
Lime	31.4
Magnesia	16.96

This, it will be noticed, presents a high grade of magnesian limestone running very low in silica and probably suitable for the lining of Bessemer converters. There are certain layers in the quarry which have a tendency to become silicious in their character, and these have to be avoided in mining.

The rock from Marks's quarry has been shipped to Newark for a number of years to be used as flux. In this case the sorting was probably not as careful as it would have been for some purposes; and consequently the following series of analyses, kindly furnished by G. H. Stone, of the New Jersey zinc and iron co., show greater silica contents.

	1	2	3	4
Silica	6.77	5.94	5.12	2.05
Ferric oxid Alumina	1.81	2.82	.75	.99 1.11
Lime	45.02	29.05	25.42	34.63
Magnesia	3.16	20.05	22.35	15.37
Phosphoric acid	.027	.....	.....	.....
Carbon dioxid	......	.....	.....	44.11

The good rock of the Sing Sing lime co. shows even less silica than that from Mark's quarry, as will be seen from the following analysis:

Silica	.87
Ferric oxid	.25
Alumina	.57
Lime	31.4
Magnesia	19.95

T ere are certain layers on the west side of the quarry which should be av ided, as they run more silicious. In structure these layers are nner than those of the purer stone and more finely crystalline. Their composition was found to be as follows:

Silica	6.75
Ferric oxid	1.08
Alumina	3.02
Lime	28.32
Magnesia	17.94

The best quality ery white lump lime.

The quarries at ster co., are most extensive and are all loc tum, which extends northeast and southwest s of about 40 feet. The firms operating the nnell & Hillery, Norcross Bros. and the Tuckah o known as J. Sinclair Co. The rock in all of these a magnesian limestone of granular character a rd. Its character is quite constant. The beds y west, and those forming the walls of the quarry are very micaceous.

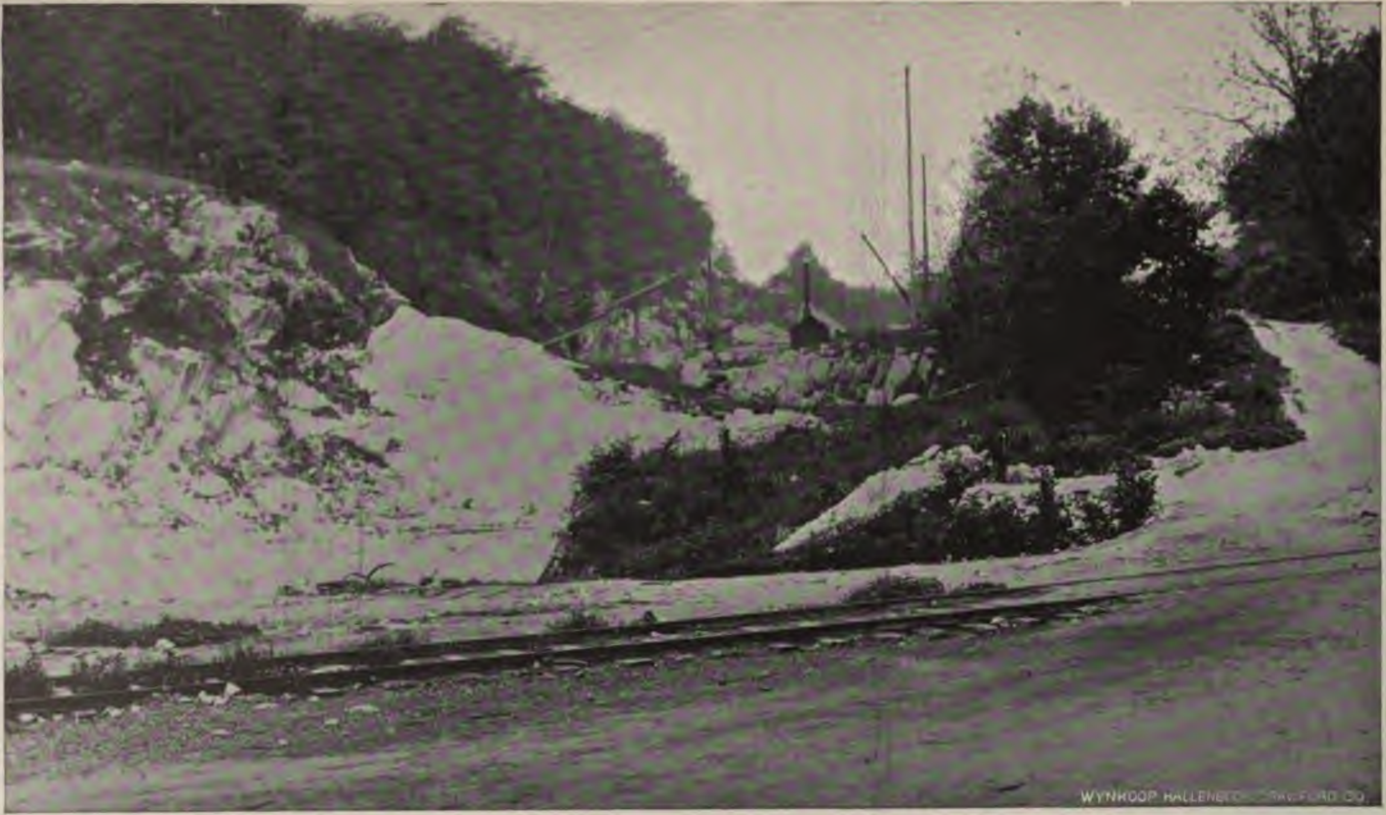
O'Connell & Hillery's (pl. 74) is the most southern quarry and is but a short distance from the Tuckahoe railroad station. The rock is used chiefly for making lime, but in recent years the manufacture of marble dust has also begun. The following analysis of the stone was furnished by the company.

Carbonate of lime	70.1
Carbonate of magnesia	25.4
Insoluble matter	2.4
	97.9

Two analyses have been given of the stone. No. 1 was made by Prof. P. de P. Ricketts, and no. 2 by W. F. Hillebrand.

	1	2
Insoluble	......	1.33
Lime	30.16	30.68

Plate 74 To face p. 830



H. Ries, photo.

Marble quarry, Tuckahoe, Westchester co. Metamorphosed Calciferous limestone

Magnesia	21.25	20.71
Carbonic acid	47.3	46.66
Ferric oxid	.21	.21
Water	.02	.16
Silica	.24	......
Alumina	.19	......
Loss	.63	......
	100	99.75

The Tuckahoe marble co.'s quarry is ¾ of a mile to the north. The quarry is about 400 feet long and 40 feet deep, and up to the present time the stone has been used for building purposes only.

Still farther to the north about ¼ of a mile is Norcross Bros.' quarry. The rock is similar in character to the preceding but the quarry is smaller.

The quarry at Pleasantville is the largest in Westchester county. It is operated by O'Connell & Hillery, successors to the Cornell lime co. The limestone is very uniform in its character, and, on account of its white color and coarsely crystalline character, has been called "snowflake marble." Nearly the entire production of this quarry is used for the manufacture of marble dust. The composition of the rock, according to an analysis given in the 16th annual report of the United States geological survey, pt 3, p. 468, is as follows:

Lime carbonate	54.62
Magnesium carbonate	45.04
Iron carbonate	.16
Alumina	.07
Silica	.1
	99.99

T[illegible]does not quite agree with an analysis made by the writer, which represents an average of the quarry as follows:

Lime carbonate	59.84
Magnesium carbonate	36.8
Alumina	.4
Ferric oxid	.25
Silica	2.31
	99.6

A small quarry wa[illegible] on near Scarsdale, but the rock contains conside[illegible]urities.

Crystalline limestone [illegible] valley of Annsville cove and Sprout brook for several [illegible]nd is exposed at a number of places, specially along the [illegible] the narrow gage railroad leading up to the Edison magn[illegible]nes. The best exposure of this is in the quarry 1¾ miles w[illegible] Peekskill rock. The rock is a fine grained, grayish whi[illegible]e, which seems to be the better quality toward the east [illegible] of the mine, where it is of a darker color. The working face exposed is over 75 feet long. The following analysis made by J. D. Irving shows the composition of the stone, and illustrates the point that far less magnesia exists in this limestone than is found in other portions of Westchester county.

Silica	2.5
Ferric oxid and alumina	1.55
Lime carbonate	81.64
Magnesium carbonate	13.5
	99.19

Other exposures of this same rock outcrop, as low ledges on the property of Mr Higgins about 2½ miles from Peekskill village. Some of these ledges show a stone of considerable purity, while in others the rock is rather micaceous.

One of the most accessible localities in Westchester county is Verplanck, where a large quarry of these pre-Cambrian limestones exists.

Yates county[1]

No beds of limestone of importance are known in this county, but marl may be found perhaps at the northern extremities of Crooked lake.

THE CEMENT INDUSTRY IN NEW YORK STATE

Two types of cement are made in New York, viz Rosendale, or natural rock cement, and Portland cement.

The former industry was the earlier established, but the latter is expanding rapidly.

Natural rock cement

The geologic position of the cement beds and their occurrence has been mentioned under "Geology of New York limestones", and in the descriptions of Ulster, Onondaga and Erie counties, specially, and the statistics have also been given. It, therefore, remains to give a brief description of the technology of the industry as carried out in this state. The general process of manufacture of natural rock cement has already been referred to (p. 678).

The localities at which the greatest development in the methods of manufacture have occurred are Rosendale, Akron and Buffalo.

Rosendale region

The cement quarries are located at Rosendale, Lawrenceville, Binnewater, Rondout and East Kingston. Owing to the great amount of rock overlying the cement bed, and its variable dips (seldom less than 25° and sometimes as much as 75° or 80°), the common method is to mine out the cement rock, leaving great pillars to support the roof (pl. 75–77). The opening along the outcrop may at times be nearly 1000 feet long. Some idea of the method of mining may be gained from the plates.

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[1] Hall, James. Yates county. (*see* Geol. 4th dist. N. Y. p. 458)
Wright, B. H. Notes on geology of Yates county, N. Y. (*see* 35th an. rep't N. Y. state mus. p. 195)

Great falls of rock sometimes occur (pl. 78) around the entrance to the abandoned workings. The bed is commonly worked down on the dip, and the slopes are sometimes 800 or 1000 feet long.

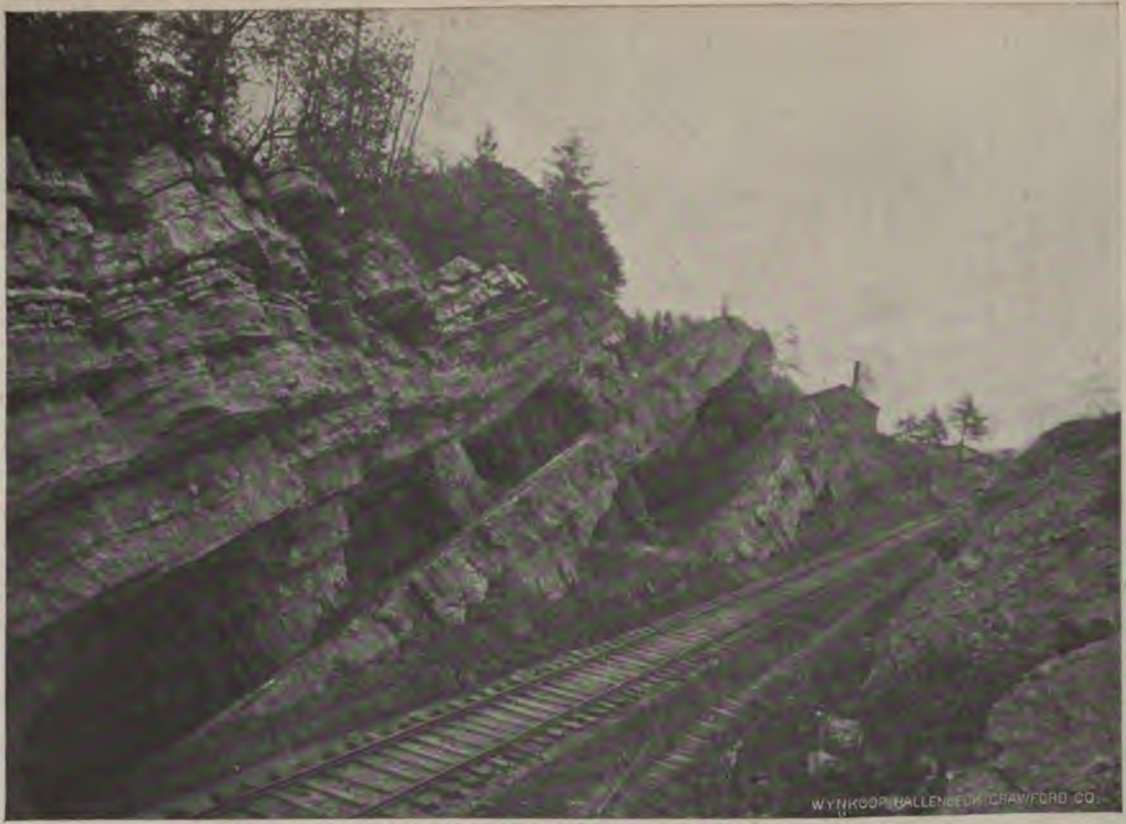
The following table gives the number of firms in this region, and other details concerning their mines, taken from F. L. Nason's report.

The method of manufacture is well illustrated by the following description of the works of the Lawrence cement co., which have a capacity of 5300 barrels a day. The rock used is taken from two beds, known as the upper or light rock and lower or dark rock. The two are mixed and broken into a suitable size for charging into the kilns. These kilns are of stone, lined with fire brick. Alternate layers of anthracite coal and cement rock are charged into the kiln, a layer of wood being placed at the bottom to light the fire when the kiln is first started.

Each day the burned material is removed from the bottom of the kiln, while fresh fuel and green rock are introduced at the top. The material drawn contains a certain amount of underburned and overburned rock, the former going back to the kiln, while the latter is thrown away. The normally burned rock is taken to the "cracker" room, where it is crushed in crackers to fragments and grains, varying from dust to hickory nut size.

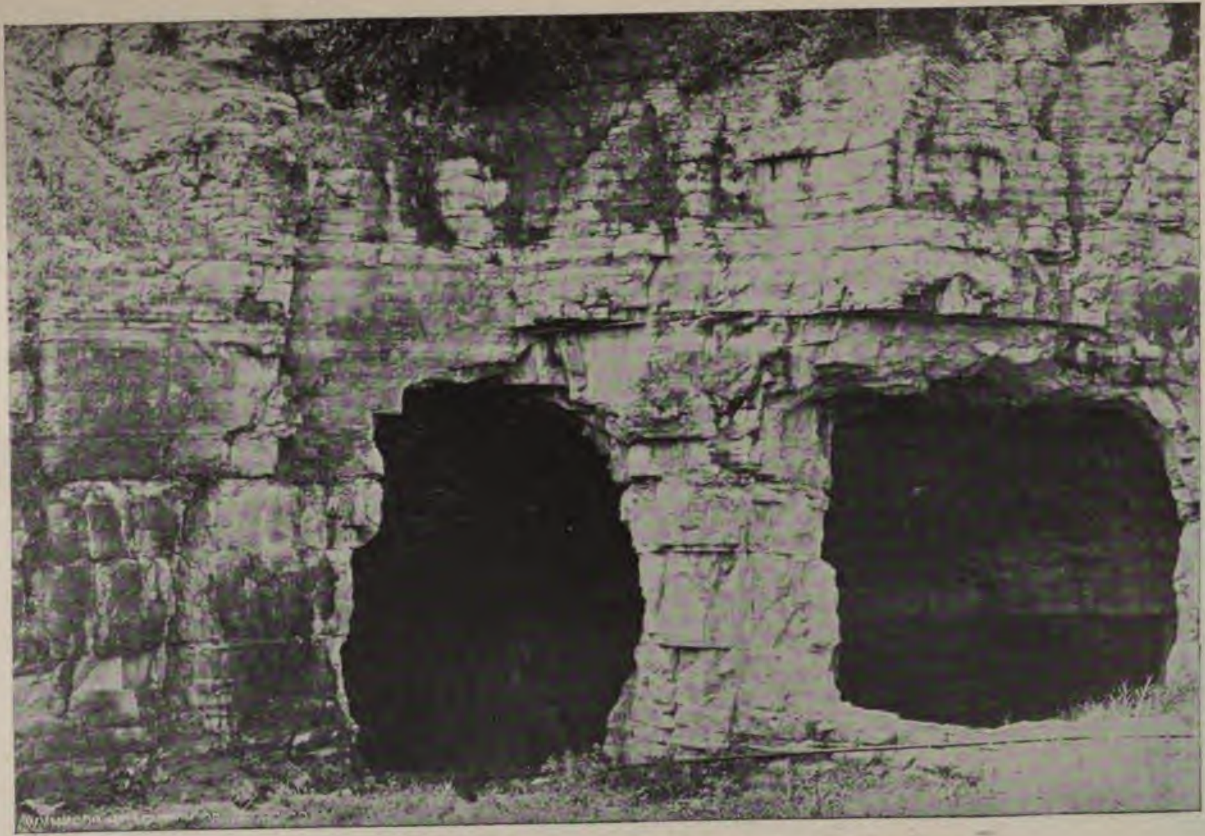
Plate 75

To face p. 834



N. H. Darton, photo. Cement quarries, one mile south of Whiteport, Ulster co. Waterlime group

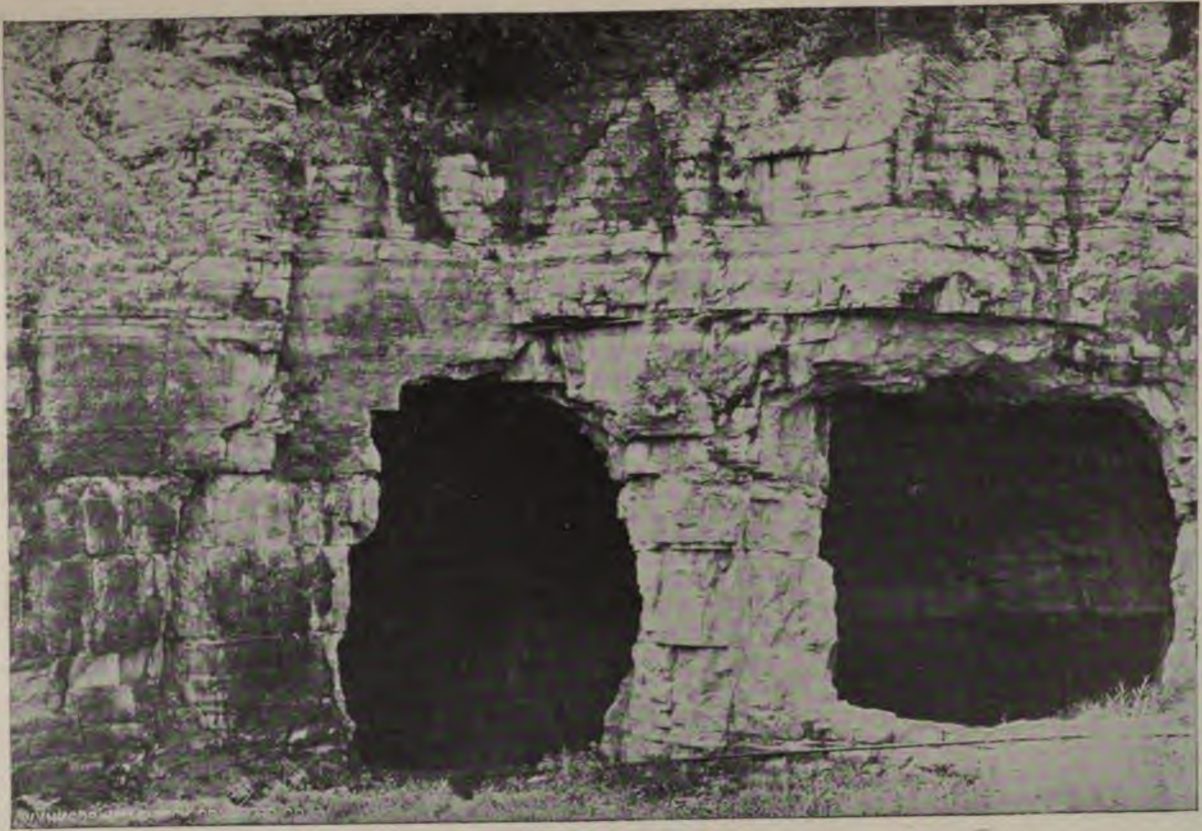
Plate



H. Ries, photo.

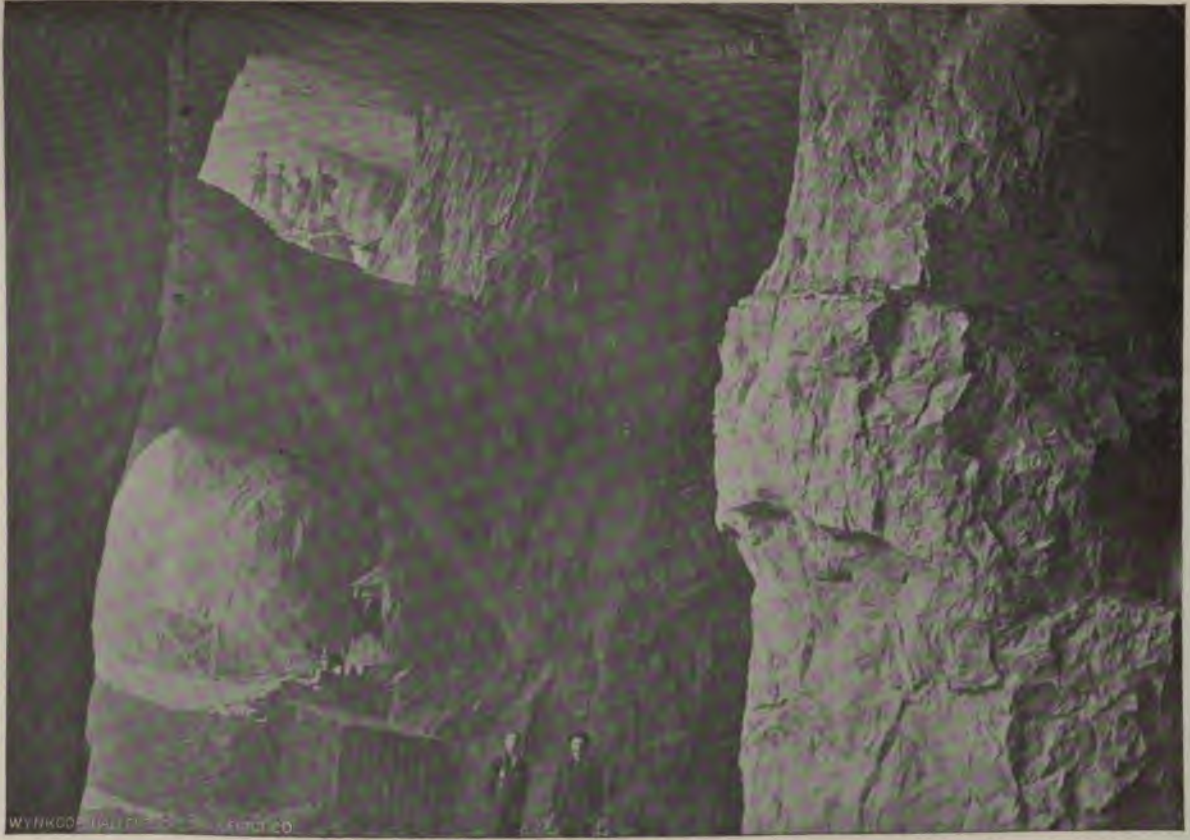
Old mine of the Newark cement co., Rondout, Ulster co. Waterlime group

Plate



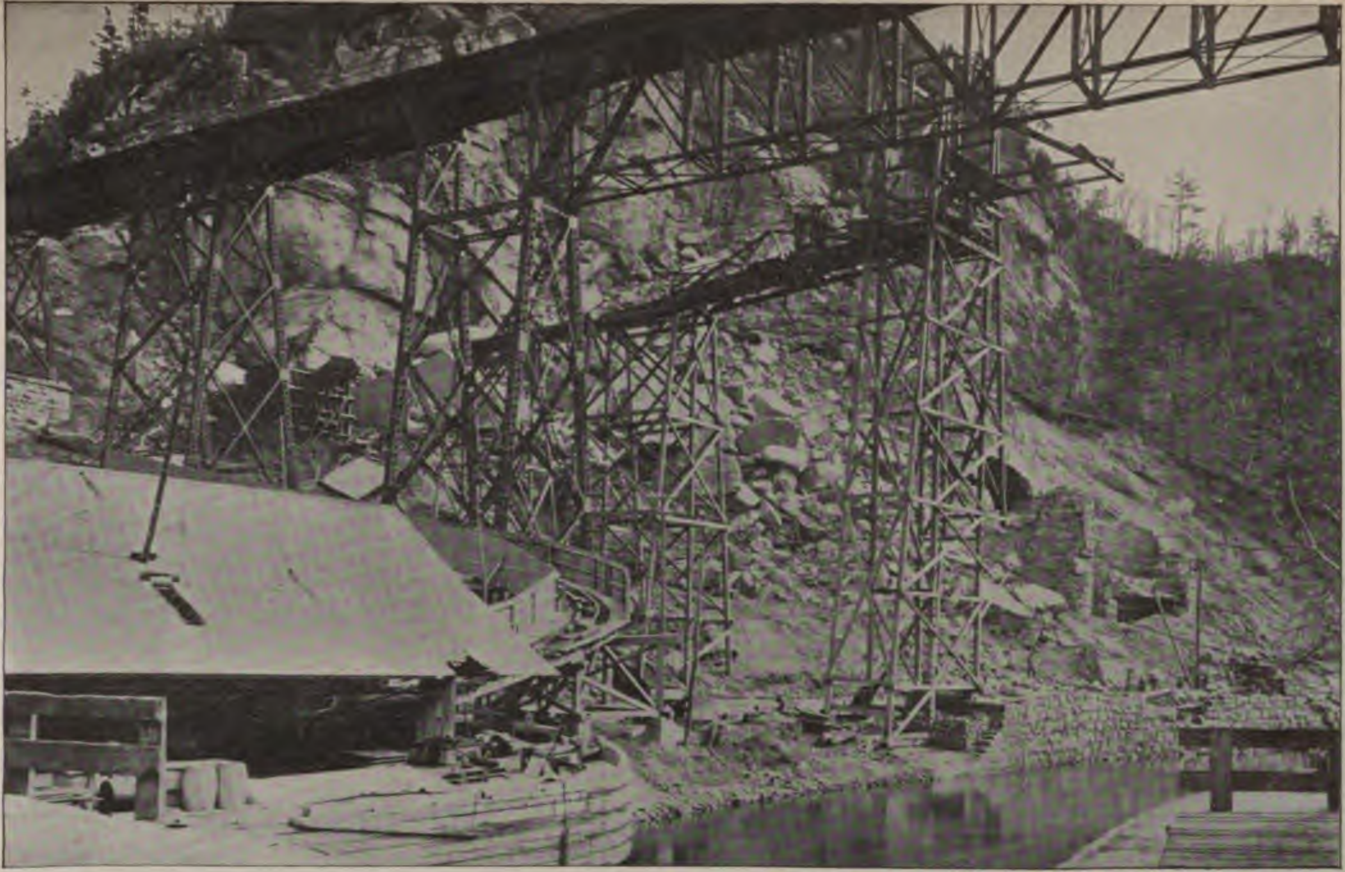
H. Ries, photo. Old mine of the Newark cement co., Rondout, Ulster co. Waterlime group

Plate 77



H. Ries, photo.

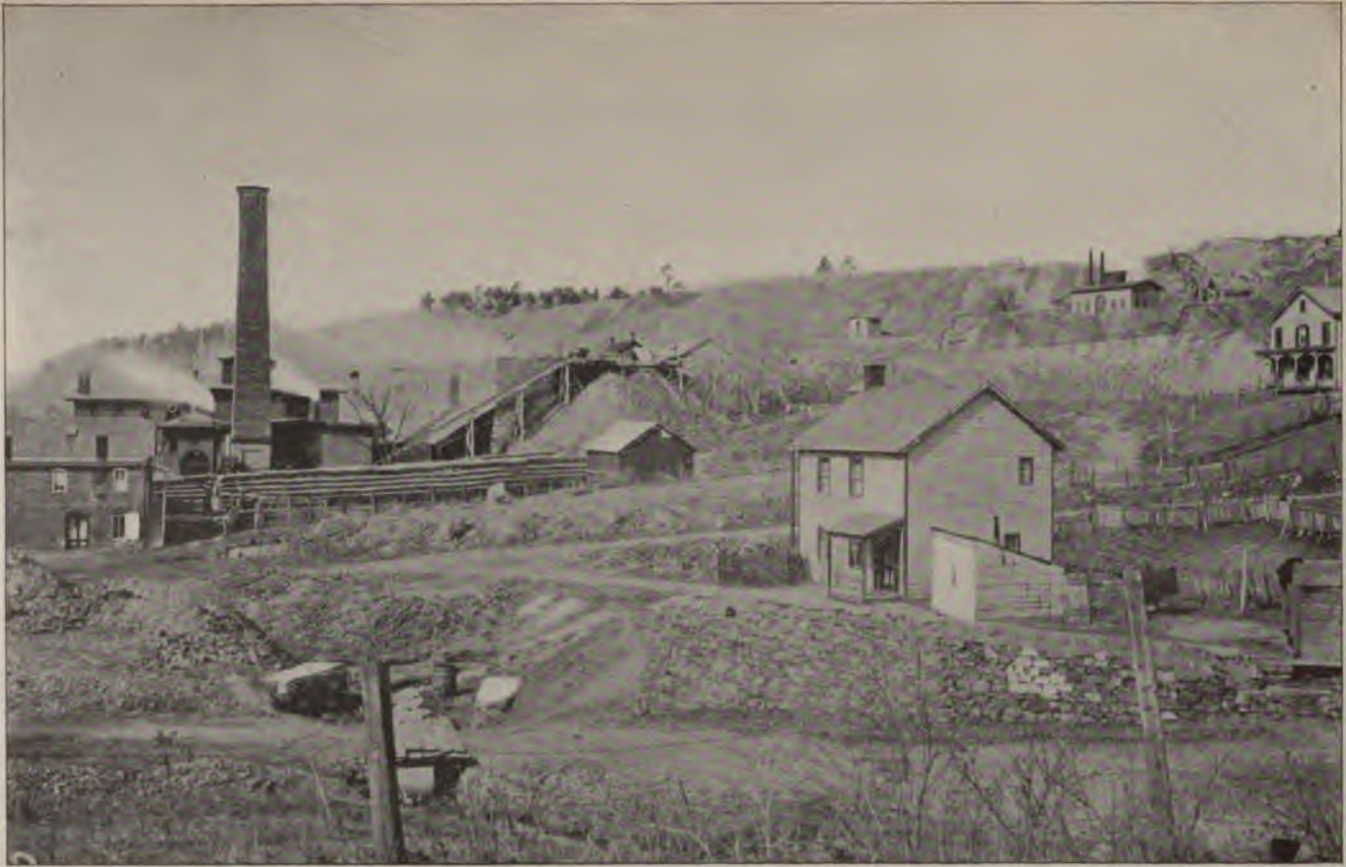
Interior view of cement mine at Rosendale, Ulster Co. Waterlime group



H. Ries, photo. Slip of rock, Rosendale

Plate 79

To face p. 834



H. Ries, photo.

Quarry and kilns, Lawrence cement co., at Whiteport

Cement mines of Rosendale region

MANUFACTURER	LOCATION	Depth worked measured on slope	Length of working face	Thickness of bed	Men in mines	Men on surface	Number of kilns
		Feet					
Newark lime & cement co.....	Rondout	250	2000	25	70	80	21
N. Y. & Rosendale cement co..	Rosendale ...						
" ..	Wilbur......	Wilbur 150	Rosendale 525	Rosendale 33	200	130	7 large, 23 small
" ..	Quicklocks ..	Rosendale 450	....	....	......	......	....
" ..	E. Kingston.						
F. O. Norton	Highfalls......	Open face	800	11	5	50	6
Highfalls & Binnewater co....	Binnewater....	300	1320	31	45	100	16
D. A. Barnhardt	Highfalls	Open face	500	32	15	33	9
J. H. Vandermark	Bunceville	"	420	30	15	18	4
Lawrenceville cement Co......	Binnewater ...	"	800	24	17	79	15
N. Y. cement co.............	Lefever Falls..	450	1000	24	100	100	13
Newark & Rosendale.........	Whiteport	160	4000	29	55	120	17
A. J. Snyder & Son	Lawrenceville .	330	150	23	30	80	5
Connelly & Shaffer...........	Quicklocks.....	300	100	30	55	95	6
Lawrence cement co	Lawrencev'le	90–1000	60–400	11–22	171	165	64
"	Rock lock ...						
"	Eddyville....						
"	Esopus						
"	Binnewater .						

These are made of cast iron, and consist of a frustum of a solid cone called the core, working concentrically within the inverted frustum of a hollow cone, both having on their adjacent surfaces suitable grooves and flanges for breaking the stone as it passes down between them. From the crackers the crushed cement is carried by means of an elevator and conveyor to a sieve 11 feet long and 10 inches wide, and about 50 meshes per inch. 25% to 27% passes this sieve. That which does not pass the sieve goes to horizontal stone mills, where it is ground between millstones, after which the two lots of fine material are mixed, and then packed in barrels for shipment.

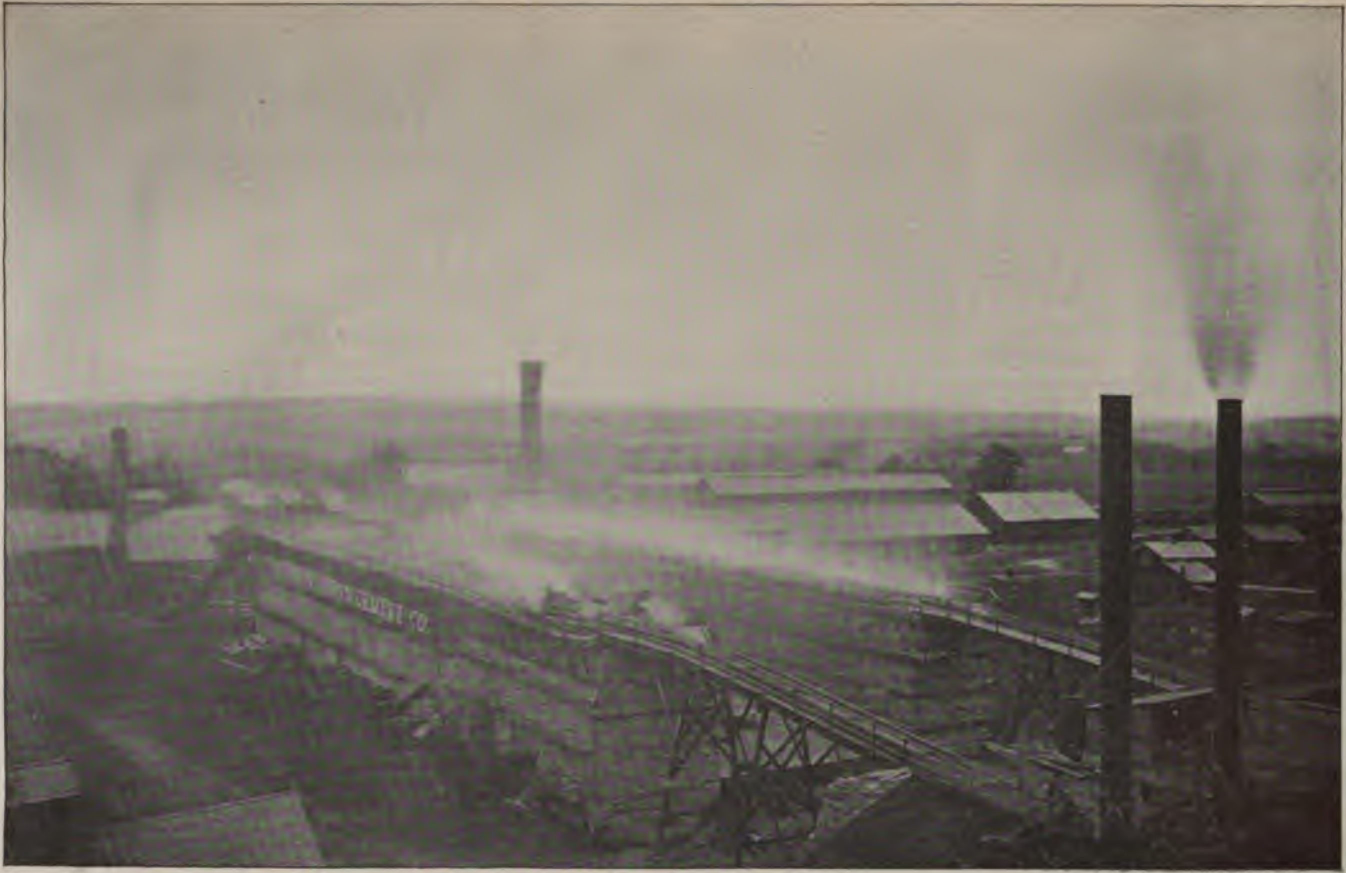
Akron district

One of the largest plants in the state is situated at this locality, viz the Cummings cement co. (pl. 80, 81); another large works also near this town is the Union Akron cement co. (pl. 82, 83).

The Cummings cement company has 575 acres of land, and the cement bed is from 7 to 8 feet thick. The beds differ from those at Rosendale in lying almost horizontally. The kilns are 34 feet high, eight of them being of rectangular cross-section, 9x22 feet in dimensions, and nine of them round, with a diameter of 9 feet. During the calcination much of the cement rock becomes clinkered, and is separated and ground by itself to be sold as Portland cement.

At this works a general system of reduction is used, consisting of 1) Sturtevant crushers; 2) Cummings pulverizers; 3) 10 run of 42 inch underrunner millstones faced with chilled iron plates; 4) 10 run of 42 inch hard Esopus underrunner millstones.

The material, as it is conveyed from one to another of these sets of crushers, is made to pass over screens, whereby such material as has been reduced to proper fineness is separated from the mass and is spouted to a general conveyor, which finally receives the material from all the grinding machines and conveys it to the packing house. Each set of crushers, while it furnishes a part of the material, reduces the sizes of the unground portion to such a degree that the material which is fed to the fourth

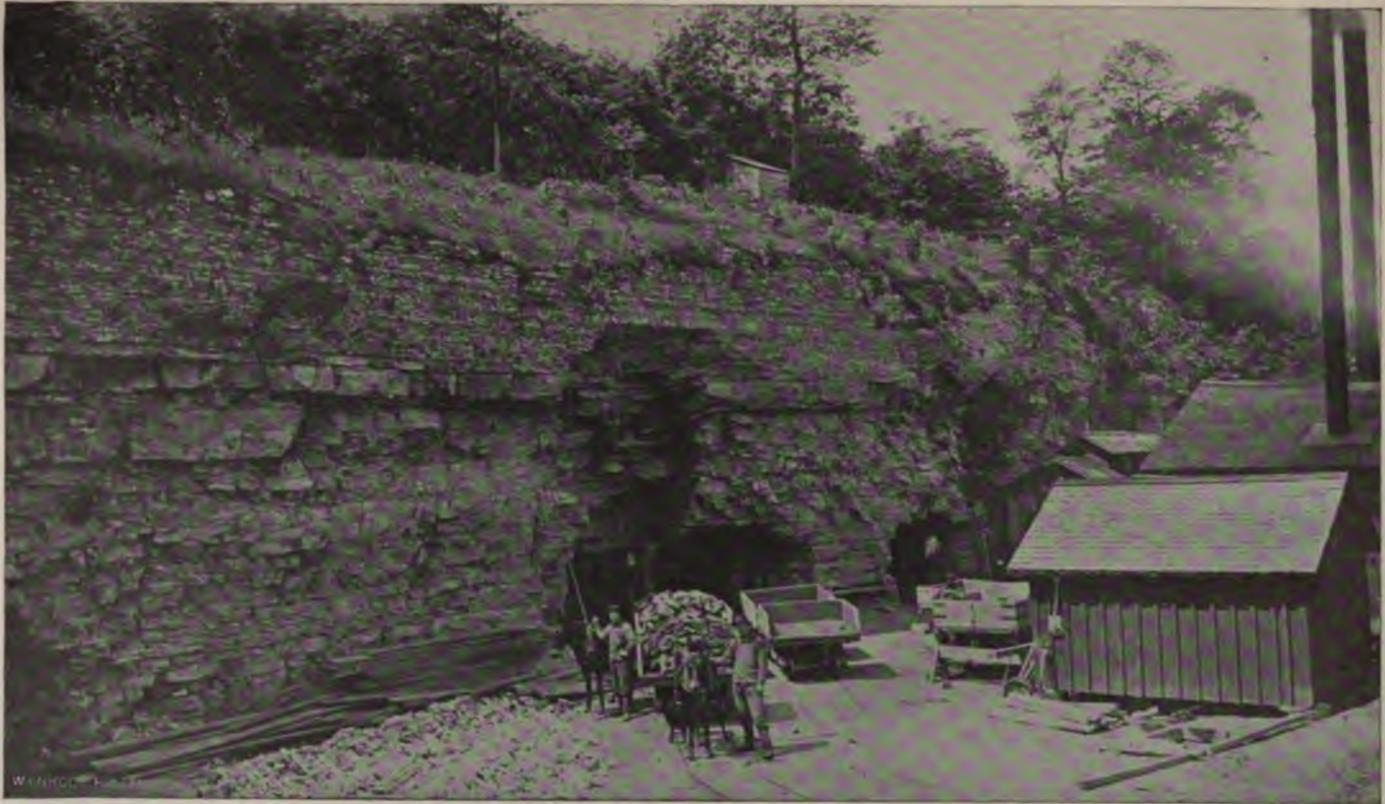


H. Ries, photo.

General view Cummings cement co.

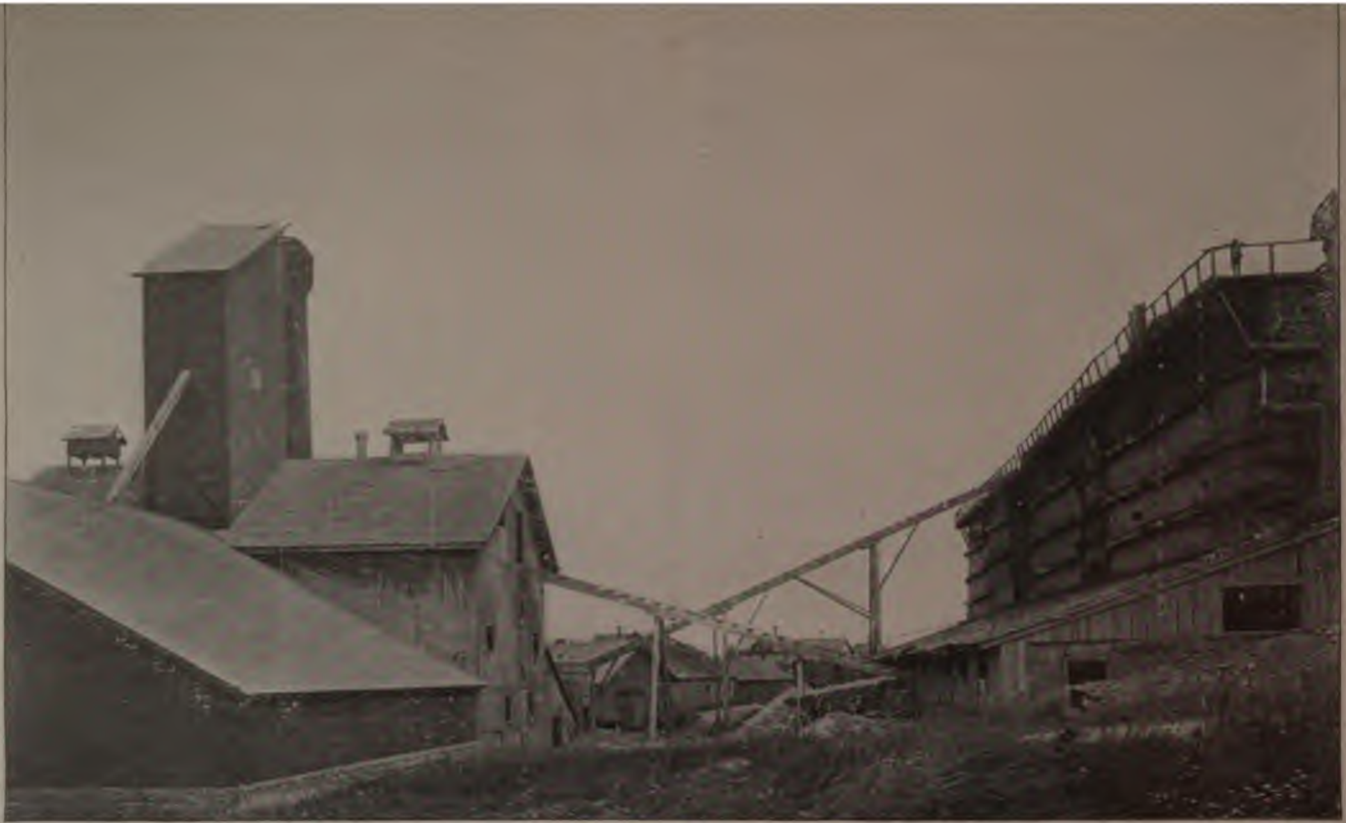
Plate 81

To face p. 836



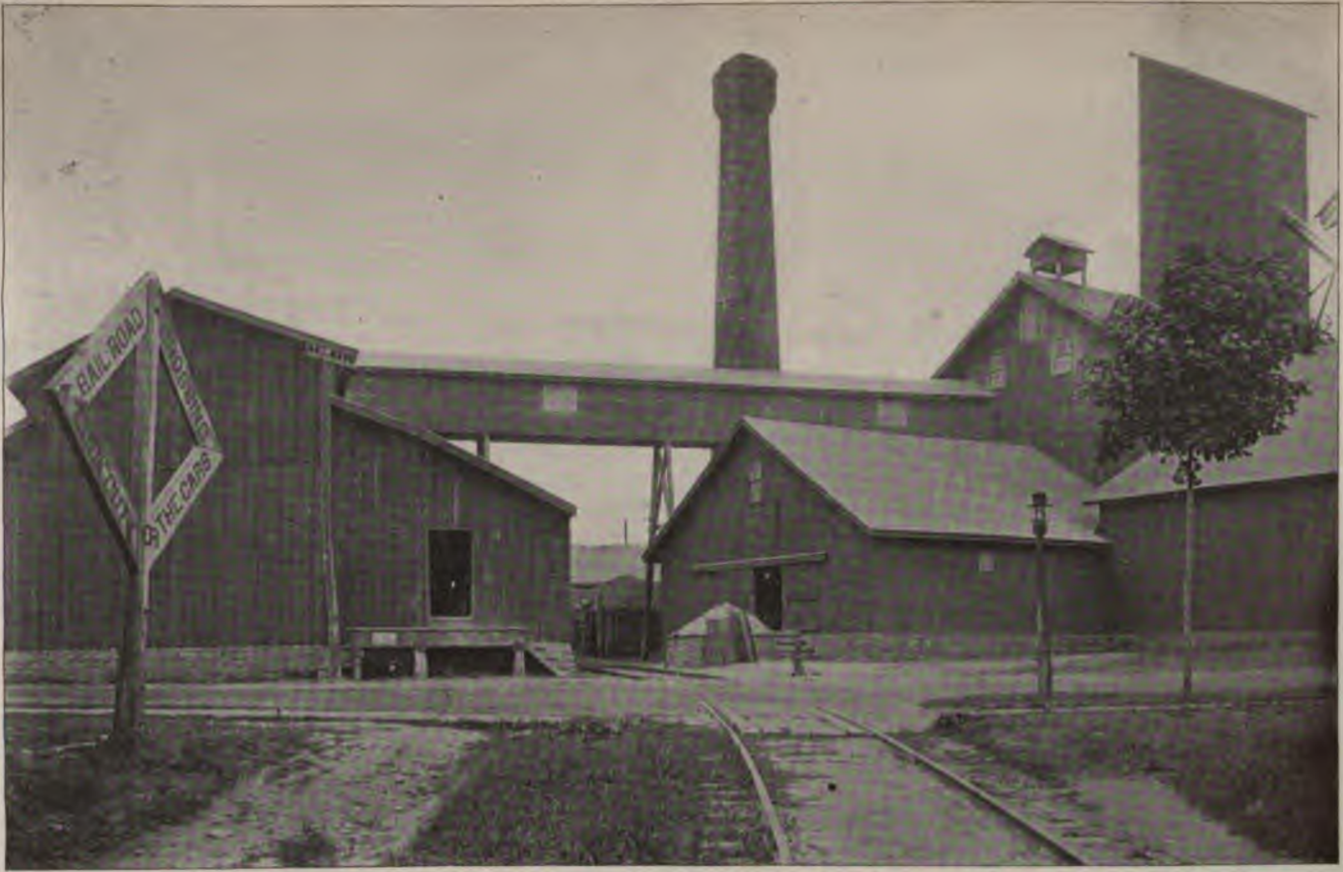
I. P. Bishop, photo.

Mine or quarry of the Cummings cement co., Akron, Erie co.



H. Ries, photo.

Kilns of Union Akron cement co.



H. Ries, photo.

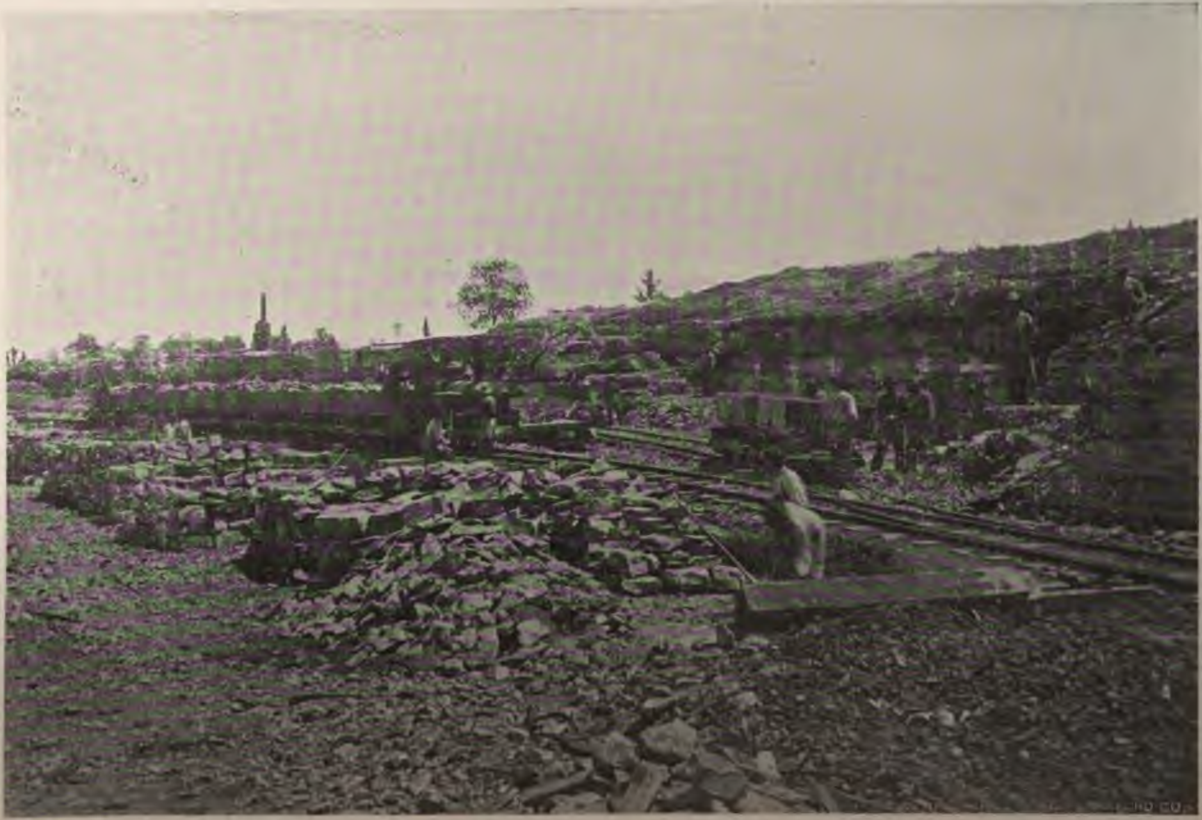
Storehouse, Union Akron cement co.

THE [illegible]
PUBL[illegible]

[illegible] AND
[illegible] ONS.

Plate 84

To face p. 837



I. P. Bishop, photo.

Quarries of the Buffalo cement co., Buffalo, Erie co. Railway for drawing stone to the crusher series is broken and worn down to the size of wheat kernels and is exceedingly hard to reduce. The harder burned portions make a cement which has a much higher tensile strength than the normally burned product.

The method of manufacture in use at the other works at Akron is somewhat similar to that employed at the plants at other localities in the state, but the kilns are in part of a more modern type, being made of sheet iron instead of stone, but, like the others, they are lined with fire brick.

The Union Akron cement co. is also contemplating the manufacture of Portland cement.

Buffalo district

The Buffalo cement co. has quarries on Main street near the belt line of the New York Central railroad (pl. 84). The cement bed underlies the Onondaga limestone. The section in its quarry shows:

	Feet
Cherty limestone	7
Massive limestone	4
Impure limestone called "bullhead"	6
Cement rock	4

The rock is burned in the ordinary stone kilns lined with fire brick, there being 10 of them, set in two rows. The rock is loaded on cars and hauled up an inclined plane to the top of the kiln, into which it is charged together with the coke that is used for fuel.

Both the normally burned and the clinkered material are fed into the grinding machinery. The first set of machines are Steadman disintegrators, and from these the material is passed over a screen, all that passes through representing the normally burned cement rock. The clinkers which are not broken fine enough by the disintegrators to pass through the screen are conveyed to a Griffin mill, where they are ground to make Portland cement. The total capacity of the plant is about 750 barrels a day.

Another cement works and quarry are located at Falkirk, and operated by H. L. & W. C. Newman, and also the Union Akron cement co.

Onondaga county

Natural rock cement, or waterlime, as it is locally called, is manufactured at a number of points in the vicinity of Syracuse. The methods of manufacture employed are similar to those in use in the Rosendale region, but the workings are all surface operations, and the cement beds are not so thick.

The following list of cement producers is taken from Luther's report, p. 271.

T. W. Sheedy. Mill and three kilns, 1 mile north of Fayetteville; quarries on Dry hill, southeast of Fayetteville.

Bangs & Gaynor. Mills and four kilns at Fayetteville; quarries on Dry hill.

J. Behan estate. Mill and four kilns, 1 mile north of Manlius.

A. E. Alvord. Nine kilns and quarries on east side of West Shore railroad at Manlius (pl. 85); mill at Syracuse.

Brown's quarry, operated by Eaton Bros. at Edwards falls, 1½ miles southwest of Manlius; mills and one kiln.

R. Dunlap, ½ mile north of Jamesville. Five kilns and mill; quarry on hill east of works.

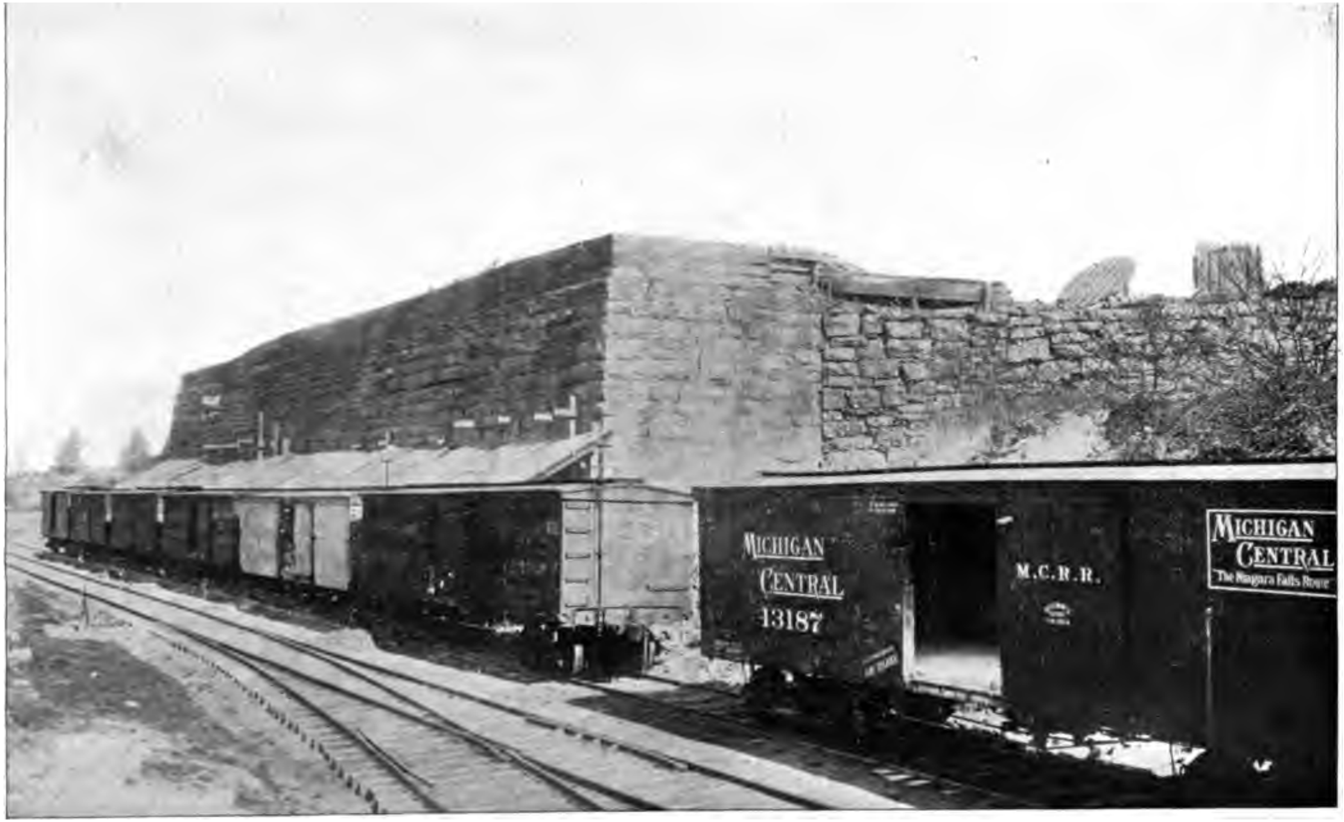
E. B. Alvord & Co. Mill and two kilns in village of Jamesville; quarry ½ mile south of works on east side of Butternut creek.

Britton & Clark. Mill and seven kilns near Delaware, Lackawanna and Western railroad at north end of Jamesville rock cut.

L. H. Walker. Cement mill near Marcellus Falls, and quarry.

P. C. Corrigan. Mill and two kilns at Skaneateles Falls, and two quarries, one on each side of Skaneateles outlet.

[Several pages by Dr Ries on the Portland cement industry which followed here, have been replaced, at the request of the director, by the sketch of that industry given in Appendix B. This change was made at the suggestion of Dr Ries, Jan. 20, 1902.]



H Ries photo.

Alvord & Co.'s kilns, Manlius

PRODUCERS OF LIME AND NATURAL CEMENT[1]

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Albany	Albany	Callanan road improvement co.	South Bethlehem
	Aquetuck	Carl Snyder	Coeymans
	New Baltimore	William Fuller's Sons	New Baltimore
	Ravena	Abraham Day	Coeymans
	"	W. V. D. H. Defriest	"
	"	David Hotaling	"
	"	William Hughes	"
	"	Conrad McCullock	"
Cayuga	Auburn	J. Bennett & Son	Auburn
	"	L. S. Goodrich & Son	"
	Rochester	B P. Smith	Union Springs
	Skaneateles Falls	Levi Starr	Sennet
	Union Springs	J. L. Shalebo	Springport
	"	G. P. Wood	Hamburg
Chenango	Oxford	William Lally	"
Clinton	Chazy	Chazy marble lime co.	Chazy
	"	L. M Goss	"
	Plattsburg	H. Behan	Plattsburg
	"	G. W. Pray	Peru
	"	T. Robinson	Plattsburg
Columbia	Hudson	Shute & Rightmyer	Jonesburg and Hudson
	Jonesburg	F. W. Jones	Greenport
Dutchess	Dover Plains	G. V. Bensen	Dover
	Pleasant Valley	Evert Russell	Pleasant Valley
	Poughkeepsie	F. R. Bain	Dover
	"	H. D. Hufcut	"
	"	M. Lawler	"
	Stoneco	Hud. Riv. stone sup. co.	Stoneco
Erie	Akron	H. L. & W. C. Newman	Newstead
	"	Union Akron cement co.	"
	Bellevue	B. A. Lynde	Bellevue
	Buffalo	E. J. Ambrose	Buffalo
	"	J. Armbruster	"
	"	Barber asp. pav. co.	"
	"	Buffalo cem. co., ltd.	"
	"	Consumers lime co.	Clarence
	" or Akron	Cummings cement co.	Akron
	"	Cutter & Bailey	Buffalo
	"	D. R. & H. Fogelsonger	Amherst
	"	Anna Gehres	Buffalo
	"	J. Gesl jr	"

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[1] For producers of Portland cement *see* Appendix B.

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Erie	Buffalo	Grattan & Jennings	Buffalo
	"	Martin Kabel	"
	"	A. P. Kehr	Clarence
	"	P. G Straub	"
	Harrishill	A. Fiegle	"
	Williamsville	J. B. & F. H. Young	Williamsville
Essex	Burlington Vt.	Burlington mfg. co.	Port Henry
	Newark N. J.	Anderson & Moynehan	Newcomb
	Willsboro Point	C. W. Frisbie	Willsboro
Fulton	Cranberry Creek	W. Kegg	Northampton
	"	Willis E. Warren	"
	Dolgeville	A. Dolge	Oppenheim
	Gloversville	Mayfield lime co.	Mayfield
	Mayfield	S. B. Warner	"
	"	Edward, Christie	"
Genesee	Batavia	A. Berthun	Batavia
	Leroy	J. H. Brown	Leroy
	"	J. Heinlich	"
	"	G. H. Holmes	"
	"	L. H. Howell	"
	"	Morris & Strobel	"
	"	Pangrazio Bros.	"
Greene	Catskill	Catskill quarry co.	Catskill
	"	G. W. Holdredge	"
	"	H. P. Palmer	"
	Climax	D. G. Haswell	Coxsackie
	Coxsackie	A. Day	"
	Smiths Landing	J. H. Gould	Catskill
	"	William Massino	"
	Urlton	J. Day	Urlton
Herkimer	Columbia	A. Manning	Columbia
	Ingram Mills	Sherman Butler	Manheim
	Little Falls	H. Jones	"
	Middleville	W. W. Mosher	Newport
	Mohawk	J. W. Humphrey	Columbia
	Newport	John Dunn	Newport
	"	Gilbert Higgins	"
	"	Newell Murray	"
	"	G. H. O'Connor	"
	"	John Sherman	"
	"	C Smith	"
	"	Daniel Toumey	"
	North Litchfield	A. R. Davies	Litchfield
	"	Charles Dickson	"
	"	G. E. Holland	"

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Herkimer	North Litchfield	J. E. Salisbury	Litchfield
	Prospect	C. L. Talcott	Russia
	West Winfield	A. P. Bradley	Winfield
Jefferson	Cape Vincent	William Anthony	Cape Vincent
	"	R. A. Davis	"
	Chaumont	Adams & Duford	Chaumont
	"	Chaumont co.	Lyme
	Clayton	Leander Denny	Clayton
	Natural Bridge	E. & W. Hall	Wilna
	Redwood	J. McDonald	"
	Threemile Bay	J. J. Barron	Lyme
	Theresa	Loth Miller & Son	Theresa
	Watertown	H. S. Cory	Leray
	"	A. Gould	Watertown
	"	S. E. Hunting	Pamelia
	"	G. J. Lefevre	Watertown
	"	A. V. Mayhew	"
	"	P. Phillips	"?
	"	E. Williams	"?
Lewis	Collinsville	H. D. Jones	West Turin[1]
	"	M. N. Potter	"
	"	R. W. Roberts	"
	"	H. Schultz	"
	"	W. Whittlesey	"
	"	B. B. Williams	"
	Harrisville	Mary Brady	Diana
	Leyden	M. Auer	Leyden
	Lowville	William L. Babcock	L. H. Carter
	"	J. T. Campbell	"
	"	Hiram Gowdy	"
	"	M. M. Lyman	"
	"	J. Moran	"
	"	J. M. Waters	"
	Natural Bridge	F. E. Ashcraft	Diana[2]
	Lyon Falls	Orville Post	West Turin
Madison	Cazenovia	J. T. Burr	Fenner
	Chittenango Falls	C. Keeler	"
	"	C. F. Keeler & Son	"
	"	D. J. Tooke	"
	"	W. M. Winchell	"
	Munnsville	F. Adams	Stockbridge
	Oneida	Mrs C. L. Faulkner	Oneida

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[1] Going out.

[2] Closed.

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Madison	Perryville	Mrs F. W. Hodge	Sullivan
	"	C. Worlock	"
	Stockbridge	T. R. Jarvis	Stockbridge
Monroe	Rochester	Foery & Kastner	Rochester
	"	Lauer & Hagaman	"
	"	J. B. Nellis, admin.	"
	"	J. B. Pike	"
	"	Rochester lime co.	Gates
	"	Whitmore, Rauber & Vicinus	Rochester
Montgomery	Amsterdam	Amsterdam city quarry	Amsterdam
	"	J. M. Griswold	"
	"	D. C. Hewitt	"
	"	H. Stain	"
	Canajoharie	William Allen	Canajoharie
	"	G. Rapp	"
	"	A. E. & D. C. Shaper	"
	Palatine Bridge	Mohawk Valley stone co.	Palatine
	Rockton	Keating & Ritter	Rockton
	St Johnsville	Allter Bros.	St Johnsville
	"	C. Fitzer	"
	"	C. Halligar	"
	"	D. Fox	"
	"	T. Nagle	"
	"	D. Place	"
	"	A. A. Smith	"
	"	W. C. Smith	"
	Tribeshill	H. Hurst & Son	Mohawk
	"	J. G. Putnam	"
	"	J. Shanahan	"
Niagara	Buffalo	German Rock asphalt co.	Lockport
	Lockport	J. Bendiger	"
	"	M. F. Heary	"
	"	W. B. Levalley	"
	"	W. E. Lockner	"
	"	Lockport stone co.	"
	"	J. Sanders	"
	"	J. Shine	"
	"	C. H. Stainthorpe & Co.	"
	"	P. H. Tuohey	"
	"	W. H. Upson	"
	"	T. G. Watson	"
	"	C. Whitmore	"

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Niagara	Lockport	J. H. Wilson	"
	"	Woodward & Son	"
	Niagara Falls	Dean & Hoffman	Niagara
	"	B. Messing	"
	"	M. O'Rourke	"
	Wolcottville	W. J. Luckman	Royalton?
Oneida	Boonville	A. J. Lee	Boonville
	Franklin Iron Works	M. Juhl	Augusta
	Holland Patent	J. G. Hillidge	Trenton
	North Weston	J. D. Vale	Weston
	"	J. H. Van Dyke	"
	Oriskany Falls	Putnam estate	Oriskany Falls
	Prospect	E. T. Thomas	Trenton
	Sauquoit	W. W. Thurston	Paris
	Utica	E. Callahan	Trenton
	"	F. E. Conley	Oriskany Falls
Onondaga	East Onondaga	J. P. Hibbard	Onondaga
	Fayetteville	Bangs & Gaynor	Manlius
	"	H. B. Ransier	"
	"	T. W. Sheedy	"
	Hartlot	P. C. Corrigan	Elbridge
	"	A. Gorham	"
	"	C. Heavern	"
	"	J. Keenan	"
	Jamesville	E. B. Alvord & Co.	Dewitt and Lafayette
	"	R. Dunlap & Co.	Dewitt
	Manlius	A. E. Alvord	Manlius
	"	J. Behan estate	"
	"	Brown cement co.	"
	Marcellus	William Malley	"
	Marcellus Falls	L. E. Walker	Marcellus
	Onondaga Castle	Kelly Bros.	Onondaga
	"	McElroy & Son	"
	"	Storrier Bros.	"
	Splitrock	J. Connors	"
	"	C. Crowley	"
	Syracuse	Britton & Clark	"
	"	Hughes Bros.	"
	"	Kelly Bros.	"
	"	Solvay process co.	"
	"	C. Thomas	"
	"	G. Wadsworth	"

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Ontario	Canandaigua	F. McNulty	Canandaigua
	Phelps	B. Edson	Phelps
	“	W. H. Johnson	“
Orange	Johnson	House & Brown	Johnson
	Newburgh	J. J. E. Hamson	Newburgh
	“	G. W. & D. C. Miller	“
	Pine Island	C. Elston	Warwick
	Port Jervis	H. S. Whitmore	Port Jervis
	Warwick	T. Burt	Warwick
Orleans	Albion	B. Johnson	Barre
	“	T. F. Staines	“
	Clarendon	M. Murphy	Clarendon
	Shelby	E. B. Simonds	Shelby
Otsego	Cherry Valley	O. H Eldridge	Cherry Valley
	“		“
	Springfield Cent'r	W. McDonough	Springfield
Putnam	Towners	P. D. Penny	Patterson
Rockland	Tomkins Cove	Tomkins Cove stone co.	Tomkins Cove
Rensselaer	Hoosick Falls	William Carey	Hoosick Falls
	“	J. Dolin	“
	“	C. McCaffery	“
St Lawrence	Bigelow	C. Williams & Co.	DeKalb
	Brasie Corners	W. Fleming	McComb
	“	R. G Hall	“
	Canton	E. E. Stevens	Canton
	Crary Mills	Ashley Church	Potsdam
	Gouverneur	C. A. Potter	Fowler
	“	H. J. Wright	“
	“	J. B. Abbott	Gouverneur
	“	Empire marble co.	“
	“	Gouverneur marble co.	“
	“	North. N. Y. marble co.	“
	“	St Lawrence marble co.	“
	Hickory	V. Ingram	McComb
	“	William Perin	“
	Norwood	G. W. Hale	Potsdam
	“	J. L. Murray	“
	Ogdensburg	M. Frank & Son	
	“	J. F. Howard	Oswegatchie
	“	J. McConville	
	“	J. H. Nevin	Oswegatchie
	“	G. A. Wright	“

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARR
Saratoga	Saratoga Springs	C. G. Slade	Greenfield
	"	I. F. Wagar	Milton
	Sandyhill	D. Sturtevant	South Glens Falls
	Saratoga Springs	M. H. Gorman	
	South Greenfield	E. Wing	Milton
Schoharie	Cobleskill	F. Baard	Cobleskill
	"	J. Brandenstein	"
	"	Cobleskill quarry co.	"
	"	William Reilly	"
	"	J. C. Rodgers	"
	"	Whalen Ross & Co.	"
	Howe Cave	Helderberg cement co.	Howe Cave
	Middleburg	A. Bishop	"
	Schoharie	C. L. Becker	Schoharie
	"	A. Brown	"
	"	E. Farquer	"
	Sharon Center	W. Crounse	Sharon Center
	Sharon Springs	F. C. Mallet	Sharon
	"	H. S. Smith	"
	"	J. Smith	"
	"	W. T. Smith	"
Seneca	Seneca Falls	J. Fisher	Fayette
	Waterloo	D. Babcock	"
	"	Edson Bros.	Waterloo
	"	G. C. Thomas & Bro.	"
Ulster	Accord	J. Bennett	Rochester
	"	G. Krom	"
	"	A. N. Longendyke	"
	"	W. H. Rose	"
	"	J. Wakeman	"
	Brooklyn	P. H. Flynn	Saugerties
	Ellenville	B. Vandermark	Wawarsing
	Kaatsbaan	W. Fiero	Saugerties
	"	L. H. Gallagher	"
	Kerhonkson	N. Christianer	Kerhonkson
	"	E. H. Jordan	Rochester
	Kingston	L. Noone	Kingston
	Mettacahonts	S. Gray	Rochester
	Napanoch	Young & Humphrey	"
	Newcomb	J. R. Sayre jr & Co.	Kingston
	New York	The Newark & Rosendale lime and cement co.	Whiteport
	Rondout	F. W. Gross	Kingston
	"	Lawrence cement co.	"

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Ulster	Rondout	Newark lime and cement mfg. co.	
	"	N. Y. and Rosendale cement co.	Rosendale
	Saugerties	P. H. Flynn	Saugerties
	Stoneridge	J. Basten	Marbletown
	"	S. Davenport	"
	Wawarsing	C. H. Hoornbeek	Wawarsing
	Whitfield	A. Barley	Rochester
	"	[illegible]on	" [1]
Warren	Glens Falls	[illegible]d lime com- [illegible] including Glens [illegible] co.	Queensbury
	"	Joint[illegible]me co.	"
	"	Reyno[illegible]s & Reardon	"
	"	Sherman lime co. and Morg[illegible] lime co.	"
	Sandyhill	Drak[illegible]tratton co. ltd.	"
	Thurman	J. Pe[illegible]r	Thurman
	Ticonderoga	I. Joub[illegible]t	Bolton
	West Troy	G. Marks	Glens Falls
Washington	Fort Edward	G. F. Harris	Whitehall
	Greenwich	H. C. Bennett	Greenwich
	Middlefalls	H. B. Bates	"
	"	J. M. Grouty	"
	"	A. Kenyon	"
	"	J. Kipperly	"
	"	P. Sullivan	"
	Sandyhill	Monty Higly & Co.	Kingsbury
	Smiths Basin	Keenan lime co.	Smiths Basin
	"	D. Nichols & Son	Hartford
	Troy	W. D. Cheney & Son	Smiths Basin
	Whitehall	T. Adams	Whitehall
	"	J. McLaughlin	"
Wayne	Joy	William Horn	Sodus
	Lincoln	T. O. Gould	Walworth
	"	William Hanson	" ?
	Sodus Center	E. B. Mather & Co.	Sodus
	"	G. A. Munn	"
	Walworth	W. L. Hall	Walworth ?
	"	O. Munn	"
	"	J. Read	"

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[1] Changed.

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Wayne	Wolcott	A. Post	Butler
	"	C. J. Walker	"
Westchester	New York	O'Connell & Hillery	Tuckahoe
	"	Snowflake marble co.	Pleasantville
	Pleasantville Sta.	Cornell lime co.	Mt Pleasant
	Ossining	Henry Marks	Ossining
	"	Sing Sing lime co.	"
	Tuckahoe	N. Y. quarry co.	East Chester
	"	Norcross Bros.	"
	"	Tuckahoe marble co.	"
	"	J. S. Young	"
	Verplanck	Brown & Fleming	Verplanck

PRODUCERS OF NATURAL ROCK CEMENT

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Erie	Akron	Cummings cement co.	Akron
	Buffalo	Buffalo cement co.	Buffalo
	Falkirk	Akron cement co.	Falkirk
	"	H. L. & W. C. Newman	"
Onondaga	Fayetteville	Bangs & Gaynor	Fayetteville
	"	T. W. Sheedy	"
	Jamesville	E. B. Alvord & Co.	Jamesville
	"	R. Dunlop	"
	Manlius	A. E. Alvord	Manlius
	"	J. Behan estate	"
	"	Eaton Bros.	Edwards falls
	Marcellus Falls	L. H. Walker	Marcellus Falls
	Skaneateles	P. C. Corrigan	Skaneateles Falls
	Syracuse	Britton & Clark	Dewitt
Ulster	Binnewater	Lawrenceville co.	Binnewater
	"	High Falls & Binnewater Co.	"
	Bruceville	J. H. Vandermark	Bruceville
	Highfalls	D. A. Barnhardt	Highfalls
	"	F. O. Norton	"
	Lawrenceville	A. J. Snyder & Son	Lawrenceville
	Quicklocks	Connelly & Shaffer	Quicklocks
	Rondout	Lawrence cement co.	Binnewater
	"	Lawrence cement co.	Eddyville
	"	Lawrence cement co.	Esopus
	"	Lawrence cement co.	Lawrenceville

COUNTY	POSTOFFICE	FIRM	LOCATION OF QUARRY
Ulster	Rondout	Lawrence cement co.	Rocklock
	"	N. Y. and Rosendale cement co.	East Kingston
	"	N. Y. and Rosendale cement co.	Quicklocks
	"	N. Y. and Rosendale cement co.	Rosendale
	"	N. Y. and Rosendale cement co.	Wilbur
	"	N. Y. cement co.	Lefever Falls
	"	Newark and Rosendale cement co.	Whiteport
	"	Newark limeand cement co.	Rondout

CHAPTERS ON THE

CEMENT INDUSTRY IN NEW YORK

BY

EDWIN C. ECKEL C.E.

Appendix A

EARLY HISTORY OF THE PORTLAND CEMENT INDUSTRY IN NEW YORK STATE

BY EDWIN C. ECKEL C.E.

It seems desirable to explain, at the outset of this brief sketch of the early history of an important industry, the very slight extent to which the nominal author deserves credit for the matter submitted. This prefatory explanation is the more necessary because, for a reason stated farther on, quotation marks and separate credits have been omitted, except in a few cases; and their absence might lead the reader to the supposition that the sketch was offered as an entirely original contribution to the history of our Portland cement industry.

In the columns of *Engineering news* for May 31 and July 26, 1900, communications were published from Messrs J. Gardner Sanderson, of Scranton (Pa.) and Edward Duryee, of Colton (Cal.) Their papers, while primarily written for the purpose of clearing up certain doubtful points regarding early use of the rotary kiln in the United States, contained many interesting facts concerning the history of the Portland cement industry in New York state.

Later, while engaged in the preparation of a paper[1] describing the present condition of Portland cement manufacture in this state, I entered into correspondence with Messrs Sanderson and Duryee regarding their early experiments, intending to make use of their notes in an introduction to the paper mentioned. The material which they placed so generously at my disposal seemed, however, of too detailed and interesting a character to be used in the manner I had purposed, particularly as such use would have required that the account should be greatly condensed.

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[1] Portland cement industry in New York. Eng. news. May 16, 1901

The present paper is, with the exception of a few facts which I have obtained from other sources, based entirely on the memoranda submitted by Messrs Sanderson and Duryee. Part of this material, as has been explained above, was published by them in *Engineering news.*

Quotation marks and separate credits have been generally omitted because, at least so far as the history of the Montezuma plant and the early Portland cement plants in the lower Hudson valley is concerned, the matter here submitted is merely one long set of quotations from the letters or papers of the gentlemen mentioned.

National Portland cement co., Kingston

The earliest experiments in the manufacture of Portland cement in this state, appear to have been those carried on in the Rosendale region about 1875–76. They were made by a Mr Dunderdale at East Kingston, Ulster co., Messrs Cornell and Coykendall furnishing the capital. The materials used were marl, brought by way of the Erie canal from the Montezuma marshes, and a clay obtained near the plant. Cement of a very high grade was manufactured, but the materials and processes used were of too expensive a character to permit the experiment to become a financial success. The details of the experiments are not at present obtainable, but some idea of the methods followed and of the general high quality of the product may be gained from the following, extracted from the published report, by Gen. Q. A. Gillmore, on the cements exhibited at the Philadelphia exposition of 1876.

It is deemed proper as a subject of general interest to refer briefly to some cements not represented in the exhibition.

The National Portland cement co., of Kingston, Ulster co. (N. Y.) has recently been organized for making Portland cement by the fourth method above described.[1] The materials employed are fullers' earth, kaolin and lime. They are thoroughly ground and mixed together in suitable proportions by the wet process, although much less water is used than in the English works or in those at Boulogne. The mixture when completed is in a rather stiff semiliquid state. In this condition it is run out upon a floor underlaid with warming flues, where it is dried to the stiff of tempered brick clay. It is then passed through a brick machine, and subsequently burnt in common continuous upright kilns with anthracite coal.

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[1] This "fourth method" here noted was, as described on a preceding page ot the report, the double-kilning process, in which the calcareous material was burned and slaked before being mixed with the clay.

Specimens of this cement have been tested several times by the writer with excellent results. On the last occasion the method adopted with the cements in the exhibition was strictly followed. 1½ inch cubes, seven days old, composed of equal parts of dry cement and sand, gave a crushing strength of 3335 lb. per cube, as an average of 20 trials, being a little higher than the best Portland cement exhibited, as shown by the table.

Succeeding this, in point of date, was a small plant at Low Point, Dutchess co., erected by the engineer and contractor for the first Poughkeepsie bridge. Some cement was made here, and used in the tower foundations, but the failure of the bridge project also ended the cement experiments.

Wallkill Portland cement co.

During the winter of 1877–78 Messrs J. Gardner Sanderson and T. T. Crane carried on a series of experiments at Croton on the Hudson. A small upright kiln was in use, with a Bogardus mill, and the power which, during the summer, was used in brickmaking. These experiments, and the analysis of a large number of specimens of possible materials convinced the experimenters that the Hudson river limestones generally contained too high a percentage of magnesium carbonate, and the clays too much free sand, to be suitable ingredients of a Portland cement. Certain strata of limestone, however, belonging to the Helderberg groups[1] (the outcrops of which extend approximately north and south, a short distance west of the Hudson river, crossing Rondout creek near South Rondout) were found to be remarkably pure and free from magnesia and well adapted to their purpose. As above stated, most of the clay deposits near the Hudson river carried too much sand to be of use. After careful search suitable clays were found away from the river, the best being found in an extensive deposit near Phoenicia, on the Ulster and Delaware railroad.

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[1] Limestone from the same horizon is now being used in the manufacture of Portland cement by two companies, the Catskill cement co. and Alsen's American Portland cement co., both plants being situated a short distance south of Catskill.

1880 the Wallkill Portland cement co. was organized. The limestone and clay properties above referred to were purchased, and an abandoned flour mill at Carthage Landing on the Hudson was leased and equipped with suitable machinery, a drying channel and two upright kilns. The manufacture of Portland cement was commenced at these works early in 1881. The product, though small in quantity, was of excellent quality and had a ready sale. Tests and reports by Messrs Clark and Maclay demonstrated the value of the cement, and the experimenters were satisfied that the manufacture could be made a commercial success on a larger scale. At both the Low Point and Carthage Landing plants gashouse coke was used for fuel.

Average analyses of the clay and limestone used are given later in this paper, in discussing the operations at South Rondout. A typical analysis of the cement made at Carthage Landing follows.

Lime	59.43
Magnesia	1.72
Peroxid iron	5.17
Alumina	8.13
Carbonic acid	.....
Silica	24.1
Water, alkalis, etc.	1.45
	100

In the latter part of 1881 work was commenced on a plant located on the limestone property near South Rondout, and works with a capacity of 200 to 300 barrels a day were put in operation in 1883. These works were equipped with Blake crushers, cone grinders, burstone mills, mixers, and formers. 16 upright dome kilns were in use, with a drying channel connected and heated by the waste gases from the kilns. The limestone and clay were crushed, ground and mixed dry; then steamed and formed into bricks, which were loaded on iron cars and run, by gravity, through the drying channels.

For some time after manufacture had been in progress at these works, the gas companies of New York and Albany had supplied the necessary coke for burning the material, but the introduction of the water gas process cut off this source of fuel supply. This left the plant dependent upon Pennsylvania coke, the cost of transportation and handling of which increased the cost of cement manufacture very largely. Mr Sanderson therefore commenced experiments on the use of crude Lima oil as fuel, but found that the clinkering of the cement materials in front of the burners prevented the heat from entering the charge. Knowing that this same difficulty had been met in metallurgic operations, and overcome by the use of rotary furnaces, his attention was directed toward such furnaces or kilns, as presenting a possible solution of the problem.

The kiln adopted was a form which had been patented in 1881 by Dr George Duryee, of New Jersey. In October 1888 one kiln was put into operation at the South Rondout works. This kiln was 50 feet long and 50 inches in diameter. The upper end was at first made 50 inches higher than the lower end, but later this was reduced to 30 inches. On trial this was found to be a very satisfactory method of burning, the one kiln handling all the material the mill could supply, and producing a uniform and high grade product. Of still greater importance was the fact that it was found possible to charge the mixed and ground raw material ectly to the kiln, without preliminary wetting, making into bricks and drying. This was the first American plant at which this practice of direct charging was followed.

In 1889 the plant was entirely destroyed by fire, and Portland cement manufacture in the lower Hudson valley ceased till 1900.

The following notes from the Rondout records establish some dates.

25 Oct. 1888. Burned about 100 barrels today; oil fuel. Ground the limestone and clay separately dry, and mixed before feeding to kiln. I b, limestone 80 lb.

25 Feb. 1889. M lay 21 lb, limestone 100 lb.

AN G CEMENT

	Per cent
Lime	65.96
Silica	18.53
Alumina and o	11.09
Potash	.12
Soda	.62
Carbonic acid	.97
Magnesia and undetermin	2.71
	100

PHYSICAL TESTS OF TENSILE STRENGTH

	Second tests
7 days = 253 lb	7 days = 306 lb
14 " = 466 "	10 " = 509 "

Representative analyses of the limestone and clay used at the Carthage Landing and South Rondout plants are as follows:

	Limestone Per cent	Clay Per cent
Lime	52.295	1.255
Magnesia	.5	2.37
Peroxid iron	.438	9.144
Alumina	.677	20.771
Silica	4.405	54.011
Carbonic acid	41.515	.4
Water and alkalis	.17	12.049
	100	100

Montezuma cement co.

In the fall of 1890 operations were commenced at Montezuma (N. Y.) The company owned 1700 acres of land, underlain by a deposit of marl and clay which varied in thickness from 4 to 20 feet. The deposit lay below the level of the Cayuga river and near its shores. It was overlain by several feet of muck, which was first dredged off and used for filling and grading for a railroad. The marl and clay ran pretty uniformly in composition, and it was therefore found practicable to excavate both materials by machinery. The bucket of the steam dredger employed brought up a ton every three minutes. Cars were run on the track under the bucket of the dredge to receive the material, and the loaded cars were then run on platform scales and weighed.

The marl containing about 50% water was drawn by a steam hoist up an incline into the second story of the works and above the upper end of a mixing machine, into which the load was dumped without drying or any other preliminary treatment. At the same time a weighed and ground portion of clay was added to standardize the mixture. The materials mixed as they gravitated toward the lower end of the machine. The entire process was practically continuous, a fresh charge being added at the upper end of the mixer every 10 minutes, while an equal amount was being gradually drawn off from the lower end in the same space of time. The mixture then passed to a stone mill that completed the mixing and ground any coarse materials. From the mill the mixture was introduced directly by a screw conveyor into the rotary kiln, using oil as fuel. This was unique not only in its length, 75 feet, but in having opposite its lower end a gas retort or combustion chamber. This chamber was heated by a coal fire and vaporized the oil as it was sprayed into it. The air blast also passed into this chamber, coming from a rotary fan blower.

In the first volume of *Mineral industry*, Mr W. A. Smith gives the following interesting contemporary account of this kiln.

Duryee's revolving furnace consists of a sheet-iron cylinder, 75 feet long, inclined toward the firing end ⅜ inch to 1 foot. The lower hot end is 6 feet in diameter for a length of 20 feet, and is lined 9 inches thick with a mixture of ground fire brick and molasses. The remainder of the cylinder, 55 feet long, has a diameter of 5 feet, and is lined with 6 inch fire brick. Only the lining at the hot end requires renewal, and this can be replaced in 10 hours, at a cost of $25. The cylinder revolves on cast iron rollers three times a minute. The power required is five horse-power.

At the lower end a small coal fire is kept up on a grate, but the chief fuel is crude petroleum, introduced in a jet which meets the hot air blast. The consumption of oil is 8 gallons per barrel of cement clinker produced. 15 barrels of oil are required to heat the furnace ready for burning cement.

The clay and marl are mixed wet and run in as a slurry at the upper end. The mixture in drying forms a sand, which moves slowly downward with the turning of the cylinder, and is finally discharged at the lower end as cement clinker of the size of small gravel. It takes two hours to run the particles through. The operation is continuous, and the product is 250 barrels per day. It is claimed that all the mixture is burned to Portland clinker.

From a series of analyses and tests, for which I am indebted to Mr Duryee, I have selected the following:

ANALYSES OF MATERIALS USED AND RESULTING PRODUCT AT MONTEZUMA

	MARL[1]	CLAY	CEMENT
Lime	47.68	.....	62.22
Silica	6.22	59.22	22.51
Alumina	1.7	20.82	9.17
Iron oxid	.66		2.54
Magnesia	.52	3.09	1.08
Carbonic acid	42.11	.....	1.86

[1] Calculated without moisture.

A report by Mr W. W. Maclay, dated Ap. 28, 1892, gives the tensile strength obtained as

	AVERAGE
Neat, 7 days	649 lb
Mortar (1:2), 7 days	245 "
Mortar (1:2), 28 days	418 "

The works at Montezuma were entirely destroyed by fire in June 1893, and have never been rebuilt. The plant is of particular interest because of the advanced technologic methods there employed. It was the first American plant in which wet raw materials were fed, without drying or briquetting, directly into rotary kilns.

In following out the history of the above plants, which bore a certain relationship either in locality or management to each other, we have overlapped, in point of date, the beginning of the present system of New York cement plants. Commencing with dome kiln plants in the Hudson valley, we have traced the development in New York of the rotary kiln, and have seen how successful from a purely technologic point of view these pioneers in the industry were. The destruction by fire of the South Rondout and Montezuma plants, however, terminated the connection of these early experimenters with New York's cement industry, and the early history of that industry may be said to end in 1893. As early as 1886, another Portland plant had been erected, but this plant was managed by an Englishman, and the problem was attacked in an entirely different manner. The earlier plants had been aggressively original and American; the plant at Warners, with its dome kilns and wet mixing, was ultra-English. And till within the past year, the typical New York plant[1] has been one using marl and clay; mixing wet, briquetting and drying; and burning in dome kilns. The Warners Portland cement co. did indeed erect a rotary kiln plant near Warners,

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[1] There was, in fact, but one exception to this rule. The Glens Falls Portland cement co. at Glens Falls, Warren co., has operated Schöfer kilns since 1894 on limestone and clay.

Onondaga co., but it was in operation only a short time, and has been shut down since 1894.

In 1900, however, two companies commenced the manufacture of Portland cement from limestone and clay, burned in rotary kilns. Descriptions of these plants, as well as a summary of the condition of the Portland cement industry in New York up to May 1901, will be found in the paper previously cited.[1] One additional plant, and less certainly two others of the same type, will commence operations during the present year.

For a detailed description of the present plants and conditions of the industry in New York, I must refer the reader to my recent paper on that subject. In the present paper it is only possible to give the following summary of those now operating.

Plants in New York in 1900

American Portland cement co. Jordan, Onondaga co. Materials, marl and clay in dome kilns. Erected 1892. Shut down during 1900. Brand, "Giant (Jordan)".

Catskill cement co. Smiths Landing, Greene co. Materials, limestone and clay in rotary kilns. Commenced shipping, July 1900, the "Catskill" brand.

Empire Portland cement co. Warners, Onondaga co. Built in 1886. Materials, marl and clay in dome kilns. Brands, "Empire" and "Flint".

Glens Falls Portland cement co. Glens Falls, Warren co. Built in 1894. Burned in August 1899. Recommenced shipping, August 1900. Materials, limestone and clay burned in Schöfer kilns. Brands, "Iron Clad" and "Victor".

Helderberg cement co. Howe Cave, Schoharie co. Began operations in 1898. Since 1900 the enlarged plant has been making extensive shipments. Materials, limestone and clay burned in rotary kilns. Brand, "Helderberg".

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[1] Eckel, E. C. Portland cement industry in New York. (*see* Eng. news. May 16, 1901) This paper has been rewritten and abbreviated, and in this form is now (Jan. 1902) presented as Appendix B.

T. Millen & Co. Wayland, Steuben co. Built in 1892. Materials, marl and clay in dome kilns. Brand, "Millen's Wayland".

Wayland Portland cement co. Wayland, Steuben co. Built in 1896. Materials, marl and clay in dome kilns. Brand, "Genesee".

Portland cement in New York during 1900-1

During the year 1900 two new plants went into operation in this state: that of the Catskill cement co. at Smiths Landing, Greene co., which began shipping the Catskill brand in July 1900, and the new Portland plant of the Helderberg cement co. at Howe Cave, Schoharie co., which commenced operations late in the year. This last company had produced small quantities of the Helderberg brand since 1898, but their manufacture of Portland on a large scale dates from the installation of the new plant. Both the corporations named use rotary kilns, and the materials in both localities are limestone and clay. The rebuilt works of the Glens Falls Portland cement co. at Glens Falls, Warren co., commenced shipping, just about a year having elapsed since their former plant was destroyed by fire. The works of the American cement co. at Jordan, Onondaga co., were shut down throughout 1900 owing to new construction at Egypt (Pa.)

In all, six plants were producers in 1900.

In the summer of 1901 the Empire Portland cement co. remodeled its works completely, installing rotary kilns.

Appendix B

MANUFACTURE OF PORTLAND CEMENT IN NEW YORK STATE

BY EDWIN C. ECKEL C.E.

The following paper was prepared at the request of the director in January 1902, when the remainder of the bulletin was in page proof. Part of its incompleteness is due to the necessity for haste in its preparation; and part to the fact that subjects which might naturally be included here had been discussed at length by Dr Ries.

The writer is indebted to the editor of *Engineering news* for permission to reprint portions of an article[1] written for that journal; and to the heads of the various cement plants in the state, who have without exception aided him in making the descriptions as complete as possible. The technology of the industry is discussed in somewhat greater detail in the paper above noted, to which the reader is referred: but advantage has been taken of the present publication to bring the descriptions up to date. As it now stands the paper is therefore a summary of the condition of the New York Portland cement industry in January 1902.

Descriptions of the plants

Alsen American Portland cement co. The plant of this company is located at West Camp, Ulster co., near that of the Catskill cement co. The materials used are limestone (from certain members of the Lower Helderberg series) and clay (Pleistocene) burned in rotary kilns. A feature of much interest in the early stages of this undertaking was the thoroughness with which exploratory work was carried on before the erection of the plant was finally decided on. Numerous diamond drill borings, and analyses of the resulting cores, satisfied the company as to the thickness and purity of the limestone.

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[1] Eckel, E. C. Portland cement industry in New York. (*see* Eng. news, May 16, 1901) The descriptions of the various plants in the present paper are reprinted, almost verbatim, from this article, supplemented in the case of a few plants by data gathered during later visits to those plants.

American cement co. The plant of this company, located 2 miles east of Jordan, Onondaga co., was erected in 1892. The works were operated without any interruption till 1900, during which year they were shut down, owing to new construction by the company at Egypt (Pa.).

The materials used were marl and clay, both obtained from a marsh near the works, another bed of marl being owned by the company nearer to Jordan station. The marl is white, and the bed varies in thickness from 8 to 15 feet. It is overlain by a thin bed of muck, and underlain by a blue clay. The muck being stripped, the marl and clay were dug, and transported to the works by a wire rope way. The clay was dried and ground separately, after which it was mixed with the marl in pug mills. The resulting slurry was spread out on a drying floor, and cut into bricks. These bricks were then loaded on platform cars, dried in tunnels heated by coal fires, and fed to the kilns. 12 kilns, of the dome type, were in use, coke being used as fuel.

The clinker was reduced, first in Gates and Mosser chushers, and finally in Griffin mills. The cement was marketed as the Giant (Jordan) brand. Analyses of the raw materials and finished product, furnished by the company, follow:[1]

	Marl Per cent	Clay Per cent	Cement Per cent
SiO_2	.14	65.68	21.86
Al_2O_3	.36	24.08	7.17
Fe_2O_3			3.73
CaO	53.16	2.01	61.14
MgO	1.5	1.75	2.34
SO_3	....	.....	1.94

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[1] Analysis by Booth, Garrett and Blair, 1898.

Catskill cement co. The Portland plant of the Catskill cement co., located at Smiths Landing, Greene co., was erected during 1899, and shipments were commenced in July 1900. The materials used are clay, from the river terraces, and limestone of Lower Helderberg age. A bucket cableway is used to transport the raw materials from the quarry and claybank to the works. Average analyses of these materials, furnished by the company, follow:

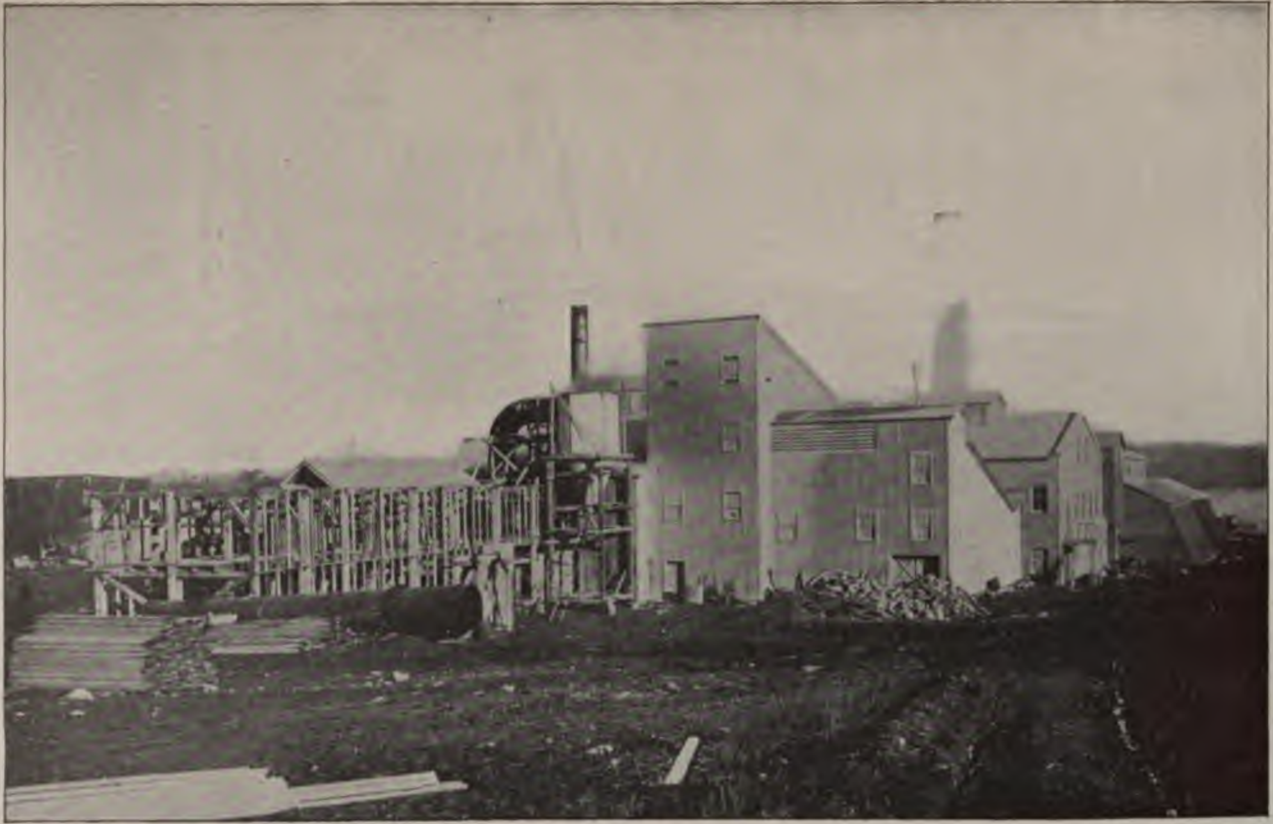
	Limestone per cent	Clay per cent
SiO_2	1.54	61.92
Al_2O_3	.39	16.58
Fe_2O_3	1.04	7.84
CaO	53.87	2.01
MgO	.52	1.58
Alkalis	.....	3.64
SO_3	.....	tr.

The limestone is dried and then reduced in a Krupp ball mill. The clay is passed through a roll disintegrator and is dried. The materials are, at this stage, mixed dry; and the mixing and reduction completed in Krupp tube mills. Two rotary kilns are in operation, having a total capacity of about 300 barrels a day. The clinker is crushed in Krupp ball mills, and receives its final reduction in Krupp tube mills. The cement is marketed as the "Catskill" brand. Analyses of the finished product follow. All were furnished by the company, 1 and 2 having been made in their laboratory; while 3 was made by H. E. Keifer Ph.D.

	1	2	3
SiO_2	22.48	21.94	23.44
Al_2O_3	6.52	6.02	6.35
Fe_2O_3	4.46	4.38	3.99
CaO	62.93	64.62	63.21
MgO	1.48	1.25	1.15
SO_3	1.3	1.12	1.22

Plate 86

To face p. 862



H. Ries, photo.

General view of works of Catskill cement co., Smiths Landing. The framework under construction is for terminal of wire rope tramway for conveying stone from quarry.

Cayuga Portland cement co. Prof. Newberry states[1] that this company "is building works near Ithaca. The material will be obtained from an outcrop of the Tully limestone and underlying shales." These underlying shales are the Moscow shales of the Hamilton group. They are rather highly calcareous, as shown by bulk analysis; but the calcium carbonate which appears in such an analysis would seem to be largely derived from the contained fossils. If this be indeed the case, extremely fine grinding and careful mixing will be necessary. The particular combination of materials to be employed at this plant is new to the state, and the operations here promise to be of much technologic interest.

Empire Portland cement co. In 1886 T. Millen & Sons commenced the manufacture of Portland cement at Warners, Onondaga co. In 1890 the plant was purchased by the Empire Portland cement co. and the works were almost entirely rebuilt, a much larger output being secured by the improvements then introduced. Since that date the plant has been in constant operation, with the exception of stops aggregating only some five or six weeks in all, caused by fires.

The materials used are marl and clay, obtained from a swamp in the vicinity of Warners, the present workings being located about ¾ of a mile from the works.

The marl bed covers an area of several hundred acres, of which about 100 acres have already been excavated.

A revolving derrick with clam-shell bucket is employed for excavating the marl, the clay being dug by hand.

The materials are taken to the works over a narrow gage railway owned by the company, on cars carrying from three to five tons each, drawn by a small locomotive.

At the works the cars are hauled up an inclined track by means of a cable and drum to the mixing floor.

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[1] 22d an. rep't director U. S. geol. sur. pt 6, cont'd. Issued as a separate, 1901.

The swamp from which the raw materials are obtained shows sections, from top to bottom, approximately as follows:

Material	Thickness in feet	
Muck	1	2
Upper bed white marl	4	7
Lower bed gray to brown marl	4	7
Sand	0	1
Bluish clay	2	5

As might be expected from the [illegible]ive color of the marls, the material from the lower bed shows, on analysis, more organic matter than that from the upper bed, for which reason more of it must be used, with the same amount of clay, than of marl from the upper bed. This distinction is accompanied by other slight but rather constant differences in chemical composition, which have also to be taken into account in the preparation of the cement mixture.

Analyses of the raw materials follow. Those marked 1 and 3 are quoted by Cummings,[1] while 2 and 4 were recently furnished me by the company:

	Marl		Clay	
	1	2	3	4
SiO_2	.26	.26	40.48	42.85
Al_2O_3	.1	.21	20.95	13.51
Fe_2O_3		.01		4.49
$CaCO_3$	94.39	91.03	25.8	22.66
$MgCO_3$	.38	.4	.99	6.92
K_2O	.....	.....	3.14	3.08
SO_3	.....	.....	.....	2.85
Organic	1.54	1.68	8.5	.....
Water + loss	3.1	6.3		

It will be noted that the clay used here runs higher in lime than does any other used in the state, the nearest approach to the above analyses being shown by that of the clay used at Wayland, which carries a little less than 20% of lime carbonate.

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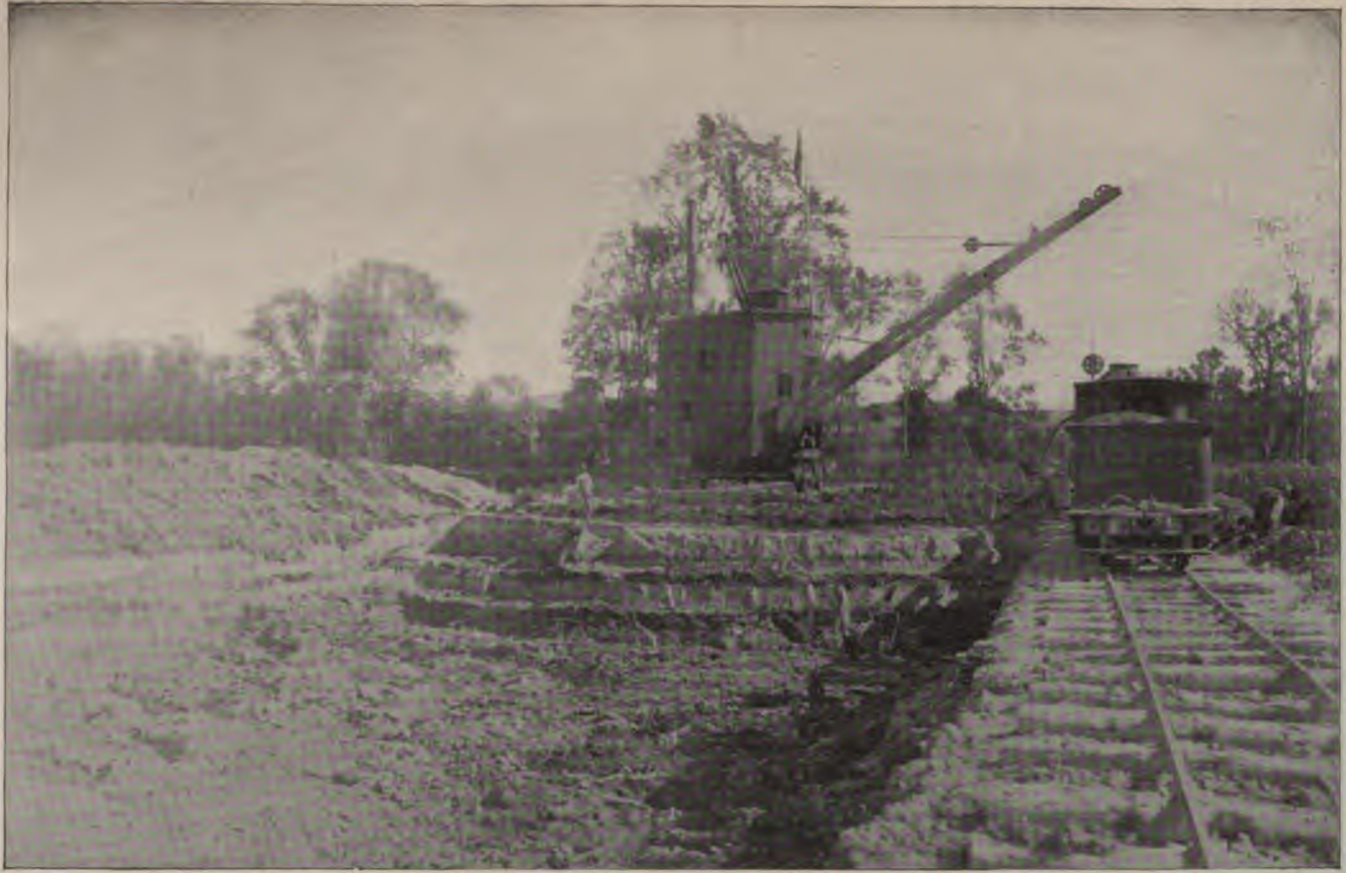
[1] American cements, p. 253.

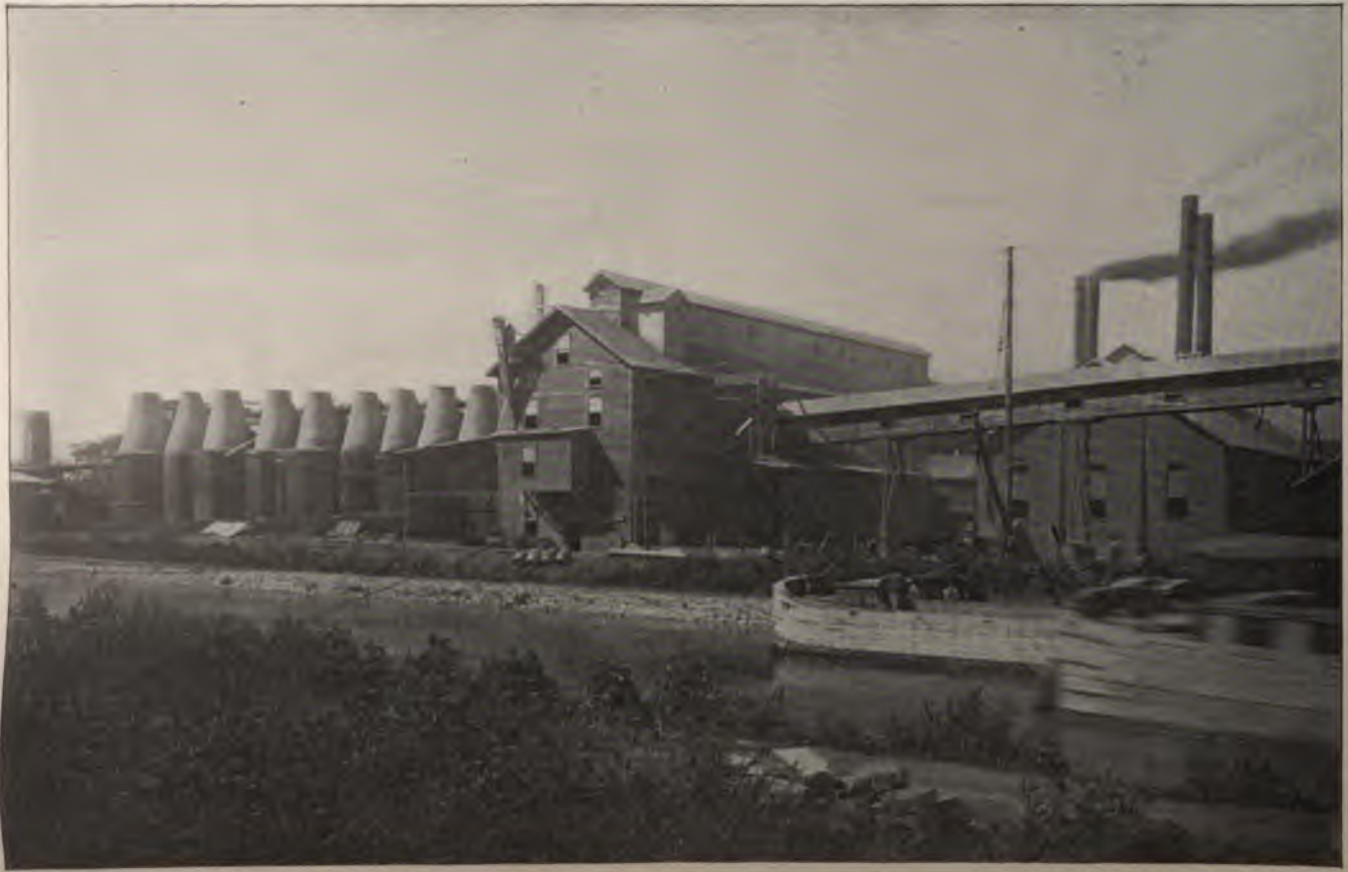


H. Ries, photo.

Marl bed at Warners

Plate 88

To face p. 865



H. Ries, photo

Old plant of Empire Portland cement co., Warners

As noted below, rotary kilns were installed by this company during 1901, and in consequence changes have been made in the methods of preparation of the materials. The processes formerly followed are given here, as being good examples of high-grade practice at a dome kiln plant.

The clay was dried in Cummer "Salamander" dryers, three being in use, after which it was carried by conveyors to the mills, being cooled before grinding. These mills were of the Sturtevant "rock emery" type, and reduce the clay to a fine powder, in which condition it is fed to the mixer after weighing. The marl was sent directly to the mixing machine, no preliminary treatment being necessary. The marl and clay were weighed, to secure proper proportions. The relative amounts used varied, of course with changes in the chemical composition of the materials, the average charge being about 25% clay and 75% marl.

The mixing was carried on in a mixing pan 12 feet in diameter, in which two large rolls, each about 5 feet in diameter, with 16 inch face, ground and mixed the materials thoroughly. The mixture was sampled and tested, after which it passed, on a belt conveyor, to two pug mills, where the mixing was completed and the slurry was formed into bricks about 3 feet long and 5 inches diameter. These bricks were placed on slats, which were loaded on to rack cars, and run into the drying tunnels. These tunnels were heated by waste gases from the kilns, and required 24 to 36 hours to dry the bricks.

After drying, the bricks were fed to the kilns, which were charged with alternate layers of coke and cement mixture. 20 kilns, all of the dome type, were in use. The coke charge for a kiln was about four to five tons, and 20 to 26 tons of clinker were produced for each kiln at each burning. From 36 to 48 hours were required for burning the charge. After cooling the cement clinker was shovelled out, and sent to the reducing department. It received its first reduction in a Blake crusher. From this it passed to Smidth ball mills, three of which were in operation. The final grinding was accomplished with Davidsen tube mills, two being in use.

The cement manufactured by this company was marked as the "Empire" and "Flint" brands. The superintendent of the company stated that the difference between the two brands lies in the fact that the Empire was made from specially selected clean clinker, while in the case of Flint no selection was made, the whole product of the kiln being allowed to go to the grinding machinery.

Analyses of the Empire brand ollow: 1 is quoted by Cummings,[1] 2 by Lewis,[2] while 3 was furnished directly by the company:

	1	2	3
SiO_2	20.8	22.04	21.98
Al_2O_3	7.39	6.45	8.2
Fe_2O_3	2.61	3.41	3.7
CaO	64	60.92	61.83
MgO	.....	3.53	1.43
Alkalis	.....	.....	.84
SO_3	.....	2.73	1.18

During 1901 this plant was entirely remodeled, the new machinery being installed by the Bonnot co., of Canton (O.). Five 6 x 60 foot rotary kilns are now in use, each kiln being equipped with a separate feed pump. The materials are prepared for burning by passing through pug mills, emery mills, settling vats, tube mills and storage tanks, from which last the slurry goes to the rotaries. The fuel used is coal, powdered in a Raymond pulverizer. A detailed description of the new plant will be given, in the near future, in a technical journal.

Glens Falls Portland cement co. In 1893 this company commenced the erection of a plant at Glens Falls, Warren co., and their cement was put on the market in 1894, as the Iron Clad brand. Six shaft kilns of the Schöfer type were installed, the

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[1] American cements, p. 36.

[2] Min. ind. 6: 99.

Glens Falls plant being therefore the second in this country to make use of this type of kiln. Though highly economical in fuel, the kiln is rather expensive in both the quantity and quality of manual labor required to operate it properly. A fire in August 1899, destroyed the plant, which was rebuilt to give a nominal capacity of 500 barrels a day, and the manufacture of cement was recommenced in August 1900.

The materials used are limestone and clay. The former is of Trenton age, and is obtained from the Glens Falls quarries. Considerable care is required in the selection and mixing of the stone from the various layers, in order to obtain a suitable and uniform product. A very clean and uniform clay, found overlying the limestone in this area, is the other ingredient. Analyses[1] of these materials follow:

	Limestone	Clay
SiO_2	3.3	55.27
Al_2O^3	1.3	28.15
Fe_2O_3		
CaO	52.15	5.84
MgO	1.58	2.25
SO_3	.3	.12
CO_2	40.98	.....
Organic and water	8.37	.....

The limestone and clay are separately dried, and crushed in Blake crushers and rolls. After being weighed on automatic scales, the materials are mixed dry and reduced to a fine powder in Griffin mills. The powder is then fed into wet mixers, where sufficient water is added to allow its being made up into bricks. These are dried in tunnels, heated by waste heat (from the boiler) driven through the tunnel system by blowers.

After drying, the bricks are burned in Schöfer kilns, using coal as fuel. The clinker is passed first through Smidth ball mills, and finally reduced in Davidsen tube mills.

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[1] Lewis, F. H. Min. ind. 6: 97.

An average analysis[1] of the Iron Clad brand shows:

SiO_2	21.5
Al_2O_3	10.5
Fe_2O_3	
CaO	63.5
MgO	1.8
K_2O and Na_2O	.4
SO_3	1.5

Sand cement is also manufactured at these works, and is discussed briefly later in this paper.

Helderberg cement co. The plant of this company is located at Howe Cave, Schoharie co. Quarries in the Waterlime group at this point have been long used for the manufacture of natural cement, while quarries higher up, both geologically and topographically, furnished a very pure limestone which was burned into lime.

In 1898, the Helderberg cement co. began to utilize the stone from these latter quarries in the manufacture of Portland cement. Commenced on a small scale, the industry would seem to have promised favorable results, as a much larger plant, belonging to the same company, was erected during 1900. The new plant has a nominal capacity of 1500 barrels a day. The materials used are limestone and clay.

As noted above, the limestone used for Portland cement is obtained from the old lime quarries, and the clay from a deposit in the vicinity. Smidth ball mills and Davidsen tube mills are used for crushing, reducing and mixing the materials. The wet process is employed and 12 rotary kilns are in use. The resulting clinker is ground in ball mills and tube mills, and the product is marketed as the "Helderberg" brand.

The various quarries at Howe Cave show exposures of the different formations from the Clinton up to the Pentamerus. Dr

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[1] Lewis, F. H. Min. ind. 6: 97.

Charles S. Prosser[1] has determined that the entire section shown consists of the following rocks, the datum being taken as the level of the Cobleskill at the suspension footbridge.

0–32 feet covered with soil.

32–56 feet green, argillaceous shales (Clinton group).

56–63 feet dark gray, massive limestones (Niagara group).

63–102 feet gray argillaceous and magnesian limestones (Waterlime group).

102–33½ feet dark blue limestone (Tentaculite group).

133½–44½ feet limestones (transitional Tentaculite Pentamerus).

144½–68 feet very massive gray limestone (Pentamerus group).

The limestone used in Portland cement manufacture is obtained from the Pentamerus and Tentaculite beds, exposed in quarries just west of the station, on the northern side of the railroad track, while the Clinton and Waterlime beds above noted are shown only in the lower quarries. Partial analyses of these upper limestones, quoted by Prosser as having been made by C. A. Schaeffer follow:

	SiO_2	$CaCO_3$
Tentaculite limestone	1.48	95.75
Pentamerus limestone	4.12	93.68

Another sample analyzed by Schaeffer gave:

SiO_2	1.27
Al_2O_3 Fe_2O_3	.73
$CaCO_3$	97.24
$MgCO_3$	1.39
SO_3	tr.

As no complete analyses of the materials actually used for Portland were obtainable, I have included this analysis, as the sample, while coming from a quarry not used for Portland cement, is evidently from similar beds, and gives a very good idea of the iron, alumina and magnesia contents of these cement rocks.

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[1] 18th an. rep't N. Y. state geol. p. 67.

Iroquois Portland cement co. This company is erecting a plant near Caledonia, Livingston co. Marl and clay will be used, in rotary kilns. Several companies have been formed to work deposits in this vicinity, but data concerning their plans are not obtainable.

Millen's Portland cement works. After having disposed of their plant at Warners, Onondaga co., to the Empire Portland cement co., T. Millen & Co. erected their present plant at Wayland, Steuben co., which commenced producing in October 1892. The works were destroyed by fire in July 1893, but were rebuilt and began shipping again in October 1893.

The materials used are marl and clay. The marl is obtained from a swamp near the mill, about 185 acres of marsh land being owned by the company. The marl deposit is about 6 feet thick. Unlike the Onondaga county deposits, however, the marl bed is not underlain by clay, and the latter material has to be brought from a bank near Mt Morris, in Livingston county. The clay deposit there worked is one of a series which occur in the terraces bordering Canaseraga creek and the Genesee river, extending more or less continuously from Dansville nearly to Rochester. The clay for cement is worked at a point about 4 miles south of Mt Morris, and is shipped over the Delaware, Lackawanna and Western railroad to the works, a distance of about 20 miles.

The clay is dried over steam coils, ground in a Potts disintegrator and mixed with the marl in a revolving mixer. The slurry is then passed through pug mills and made into bricks. These bricks are dried in tunnels, and burned in dome kilns, 16 of which are in operation. Blake crushers, Millen crackers, and Sturtevant rock emery mills are used in the reduction of the clinker. The cement is marketed as Millen's Wayland.

H. Ries, photo.

Plant of Millen cement co., Wayland

Analyses of the raw materials and of the finished product, furnished by the company, follow:

	Clay	Marl	Cement	
SiC_2	45.21	.42	21.08	22.19
Al_2O_3	19.08	1.08	9.56	9.72
Fe_2O_3	6.74			
$CaCO_3$	19.94	93.5	....	....
CaO	....	....	64.68	63.08
$MgCO_3$	3.27	2.13	....	....
MgO	....	....	1.85	2.04
$CaSO_4$	1.55	2.01	....	....
SO_3	....	....	1.93	1.75
Moisture and organic matter	4.17	.86	....	....
Alkalis and loss	....	....	.9	1.22

The analyses of the clinker were made for the company by Dr F.E. Engelhardt, of Syracuse (N. Y.)

Wayland Portland cement co. The plant of this company is located at Perkinsville, in the town of Wayland, Steuben co. It was erected in 1896 and has operated continuously to date.

The materials used are a light colored marl which occurs in a deposit 2–14 feet thick, overlain by 6 inches to 3 feet of muck, in a marsh near the works, and light gray (Pleistocene) clay from Mt Morris, Livingston co., for their marl deposit, like that of Millen's, is not underlain by clay. Analyses of the raw materials, furnished by the company, follow:

	Marl
Lime	54.4
Silica	.54
Fe and Al oxids	.56
MgO	2.34
Loss on ignition	42.2

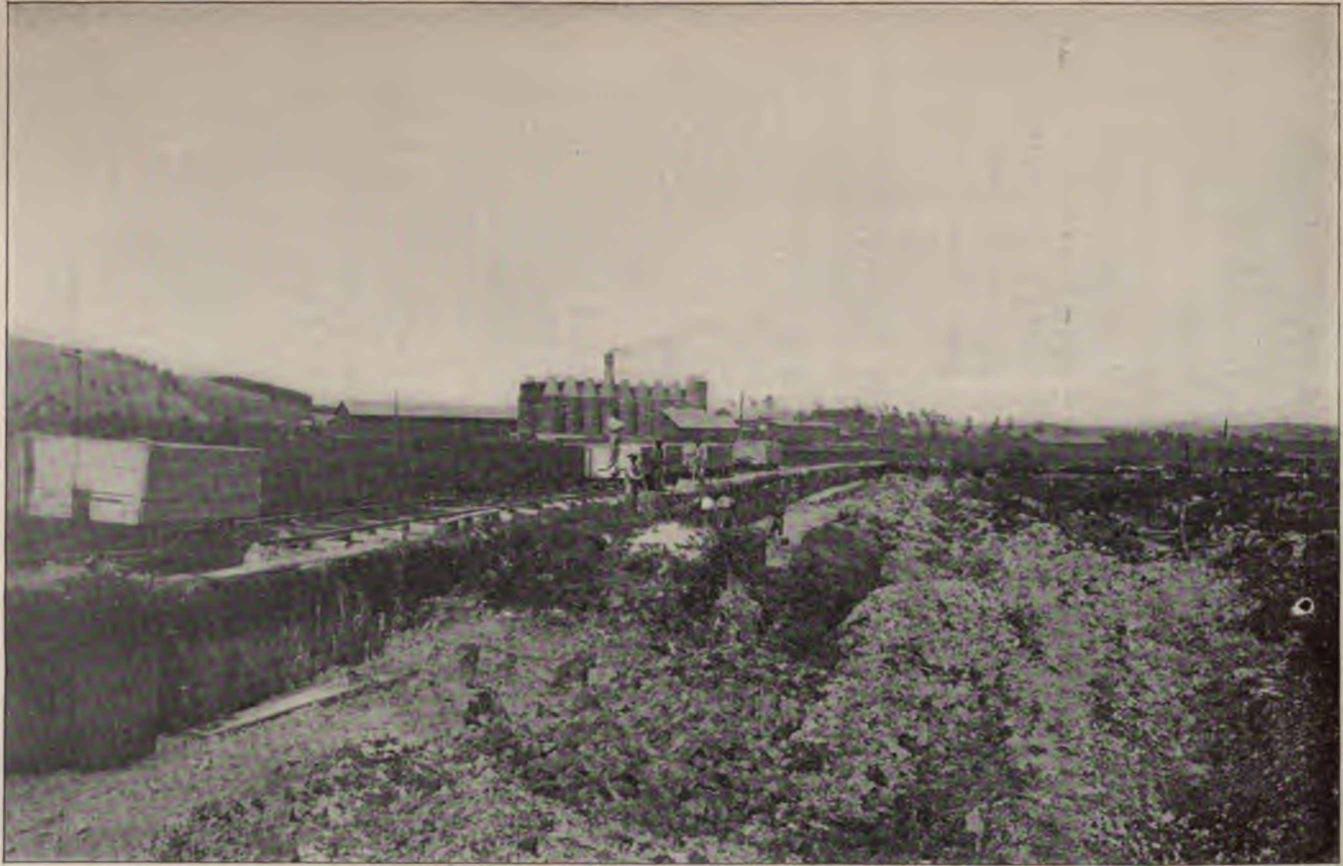
	Clay
Silica	53.5
Lime	5.15
Fe and Al oxids	24.2
MgO	2.15
Loss on ignition	14.1

The clay is dried over steam pipes, broken to about ¼–½ inches size in a Potts disintegrator; and sent through a Bullock burstone mill, which grinds to about 16 mesh. It is then weighed, and mixed with the wet marl as both are shoveled into the chutes leading to the revolving mixer. The mixture then goes to the pug mills, and is made into bricks, which are sent to the drying tunnels. The lower tier of these tunnels is heated by direct heat, on the Cummer system; the upper tier by exhaust steam. 16 dome kilns are in use. From the kilns the clinker goes to an 18 x 30 inch Blake crusher; then to dry pans, receiving its final reduction in Sturtevant rock emery mills. The product is marketed as the Genesee (Wayland) brand.

Allied products

Sand cements. Two companies, under practically the same management, are at present engaged in the manufacture of sand cement. These are the Standard silica cement co., whose works at Long Island City were described in detail in *Engineering news* of April 16, 1896, and the Glens Falls Portland cement co. At the plant of this latter company, their Iron Clad cement is used, the resulting sand cement being marketed as the Victor and Adirondack brands, the latter carrying a larger proportion of sand. At the Long Island City plant the sand was first dried in Cummer dryers; then screened, mixed with the cement in the proper proportions, and ground in Davidsen tube mills.

"Natural Portlands." Two firms in New York state manufacture, in addition to their natural cements, brands which are marketed as "natural Portlands." The limestone is fed, without



H. Ries. photo.

Plant of Genesee Wayland Cement Co., Perkinsville.

previous grinding or admixture, direct to the kilns. The resulting cement differs from a true Portland in carrying a lower proportion of lime (45%–50%) and higher magnesia (5%–10%). The cements will usually pass all Portland requirements, though not so finely ground as the normal Portlands.

Slag cements. Some time ago the Knickerbocker cement co. was organized for the purpose of making slag cement, the intention being to use the slag from the furnaces of the Poughkeepsie iron co. Operations were suspended, owing to financial difficulties not in any way connected with the cement manufacture itself; and at present no slag cement is made in this state. A brief discussion[1] of the technology of this type of cement will be found in a recent issue of *Engineering news.*

Notes on Portland cement materials

Three different combinations of materials are at present in use in New York state; while another may be utilized in the near future. Those now in use are:

1 Marl and clay

2 Limestone and clay

3 Limestone and shale

To these may be added, as of probable future use

4 Argillaceous limestone and pure limestone.

The technology of the industry has been discussed at length by Dr Ries, in the earlier portion of this bulletin; but a brief statement of the leading methods and features of the industry, as conditioned by the materials used, may be of interest.

1 **Marl and clay.** Compared with limestones, the marls are easier to excavate and easier to reduce. They contain, on the other hand, a greater proportion of organic matter and water, per ton of excavated material, than do the limestones. For this reason their transportation and handling, both between bed and mill, and in the mill itself, entail a greater expense for each barrel of finished

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[1] Eckel, E. C. Slag cement manufacture in Alabama. (*see* Eng. news Jan. 23, 1902)

product. A marl deposit is a limited affair, though in the case of a large marsh or old lake bed the limits may be so large as to be safely disregarded. Limestone beds, on the other hand, are practically limitless, the extent to which the bed can be followed being limited only by questions of economical extraction.

Marl deposits of workable size are rare in New York state, and not all of those large enough for use are located well with regard to transportation routes. Three active plants in this state use marl and clay: two in Steuben county and one in Onondaga county. The former are at a disadvantage in respect to location, which is slightly increased by the fact that their marl beds are not underlain by clay, necessitating bringing the latter material, from some distance, by rail.

2 Limestone and clay. At present four New York plants are engaged in the manufacture of Portland cement from a mixture of limestone and clay. Of these, the earliest established was that of the Glens Falls Portland cement co. At this plant limestone of Trenton age is used, with a (Pleistocene) clay, burned in Schöfer kilns.

The Glens Falls plant is unique, in this state, so far as type of kiln used is concerned. The merits and defects of the Dietzsch, Schöfer and other types of improved nonrotary kilns, have been discussed in considerable detail by various authors. The fact that the Glens Falls product is of such high grade should not, of itself, be considered as an argument in favor of the Schöfer kiln, as this particular plant has always been favored as regards management. The other three plants are located at various points along the Helderberg escarpment, and use limestones derived from several different formations of the Lower Helderberg series. For purity, thickness and location (both with respect to clay banks and to great transportation routes) these limestones can hardly be equaled, and it seems certain that the center of the New York Portland cement industry will eventually be in the Hudson river valley.

3 **Limestone and shale.** The use of this combination of materials is confined, at present, to a single plant. If this plant be successful, it is probable that its example will be extensively followed, for exactly similar materials outcrop on the shores of Canandaigua, Seneca, Cayuga and other lakes of central New York. Certain technologic difficulties in the use of these materials are noted in an earlier part of this paper, and the progress of the enterprise will be followed with much interest.

4 **Argillaceous limestone and pure limestone.** This type of mixture, used so extensively in Pennsylvania and New Jersey, has not been utilized, as yet, in this state. It is practically certain that deposits of this type of material exist in at least one county of the state, but no attempt has been made to map or develop them. Prof. Spencer B. Newberry has pointed out that[1] an argillaceous limestone used with a comparatively small quantity of a purer limestone, as in the Pennsylvania and New Jersey plants, possesses one decided advantage over a limestone and clay mixture, inasmuch as less thorough mixing and fine grinding is required, for even the coarser particles of the argillaceous limestone will vary so little, in chemical composition, from the proper mixture, as to affect the result but little, should either mixing or grinding be incompletely accomplished. This argument bears against a marl and clay mixture as well as against a limestone and clay mixture, though to a less extent.

Mr F. H. Lewis has also discussed the advantages possessed by this type of material, and comes to the same decision regarding its superiority over the limestone and clay mixtures. The New York plants, however, show that it is possible to produce good Portland cement from limestone and clay; and the fact that several Pennsylvania companies are contemplating the establishment of plants in the Hudson river valley would seem to be proof that cheap cement can be made there.

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[1] Mineral resources of United States. (*see* 20th an. rep't U. S. geol. sur. 1898, pt 2, p. 545; 22d an. rep't U. S. geol. sur. 1900, pt 2.)

One of the prominent changes that has taken place recently is that in the relative number of plants using marl and using limestone. This change is shown in the following table.

		1899	1900	1901
Active plants using	marl and clay......	4	3	3
	limestone and clay..	1	3	4
	limestone and shale,	0	0	1

Another very significant feature is shown by the following table, giving the types of kiln used:

		1899	1900	1901
Active plants equipped with	dome kilns..	4	3	2
	Schöfer	1	1	1
	rotary	0	2	5

Appendix C[1]

TESTS OF CEMENT MADE BY THE STATE ENGINEER DURING 1897-1900

BY EDWIN C. ECKEL C.E.

I am indebted to Mr Edward A. Bond, state engineer, and Mr William Pierson Judson, deputy state engineer, for permission to use the data on cement tests, here briefly discussed. Mr Russell S. Greenman has kindly aided me in many ways. My thanks are also due to Mr Joseph Morje, of the New York state museum, for aid in the preparation of both manuscript and proof.

The series of cement tests tabulated and discussed were made during 1897, 1898, 1899 and 1900, in the cement testing laboratory of the state engineer's office, Albany N. Y. They are of value as they represent tests on various brands made during a comparatively long period in one laboratory. The sequence of the tests was interrupted only by one change of operators, and by one change of testing machine, both of which occurred during 1900. Mr Charles M. Pepson was in charge of the cement testing work from 1897 to July 1, 1900, when he was succeeded by Mr Russell S. Greenman, who is in charge at the present date.

As the cement samples were taken from barrels submitted for use, the results are of interest as showing the average quality of the various brands as shipped for use on actual work. The cements tested were, in general, those submitted for use on the canal improvements. A circular issued in 1899 by Mr Edward A. Bond, state engineer, offered the use of this laboratory for the testing of cements sent in by town and county officials, and some of the cement tested during 1900 came in under this offer. A number of samples have also been tested in this laboratory for Mr George L. Heins, state architect.

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[1] Written in April 1901.

Specifications

The specifications under which the cements intended for use on the canal improvements were submitted, were, from 1896 to 1899, as follows.

Portland cement must be of the best quality and of such fineness that 95% of the cement will pass through a sieve of 2500 meshes to the square inch, and 90% through a sieve of 10,000 meshes to the square inch. Portland cement when mixed neat and exposed one day in air and six days in water, shall withstand a tensile strain of not less than 400 lb to the square inch; and when mixed in the ratio of 3 lb clean, sharp sand to 1 lb of cement, and exposed one day in air and six days in water, it shall withstand a tensile strain of not less than 125 lb per square inch.

Natural hydraulic cement must be of the best quality, and of such fineness that 90% will pass through a sieve of 2500 meshes to the square inch, and 80% through a sieve of 10,000 meshes to the square inch. Briquets, made of equal parts of natural hydraulic cement and crushed quartz, immersed in water as soon as they are sufficiently hard to sustain a $\frac{1}{24}$ inch wire weighted with 1 lb, must show a tensile strength of 65 lb to the square inch at the expiration of seven days; but briquets showing less than such strength will be held until 28 days have elapsed, when, if they then show such strength as to sustain as many pounds to the square inch above 125 as the seven day test shows them to have fallen below 65, they will be deemed to have passed this test.

Briquets made of neat cement must not set so as to support a $\frac{1}{12}$ inch wire with a load of $\frac{1}{4}$ lb in less than 15 minutes. Briquets of neat cement must not show checks or cracks when immersed in water for seven days after mixing.

Portland and natural cements manufactured in this state will be given the preference for this work, provided they satisfactorily pass the tests called for by these specifications.

The specifications at present in use are the following.

28 **Requirements hydraulic cement.** American Portland cement or American natural cement, as may be specified, shall be used and shall be of a brand known by prior use on extensive works to be of the best quality. Any cement not so known may be declined without testing.

29 **Storing.** Provision shall be made by the contractor for storing cement in a dry place and delivery shall not be made until the state engineer has been notified to inspect the cement and to take samples for which all facilities shall be offered by the contractor. The contractor shall replace at his own cost any cement which may be damaged while stored.

30 **Samples.** Samples will be taken by the engineer, at once on delivery, from every 10th barrel or from the equivalent of the 10th barrel, when packed in sacks, and will be numbered consecutively throughout the progress of the work; each sample shall fill a 4 inch cubical box, and each lot of samples shall be forwarded by express to Albany for separate tests, the results of which may be expected in 10 days.

31 **Tests.** These tests will follow the practice recommended by the American society of civil engineers and will be: 1st, for fineness; 2d, for soundness; 3d, for time of initial set; 4th, for tensile strength; 5th, for composition by chemical tests.

32 **Required fineness.** Cement shall be ground to such fineness that 95% by weight will pass through a standard sieve of 2500 meshes per square inch and 90% by weight will pass through a standard sieve of 10,000 meshes per square inch.

33 **Soundness.** The cement shall endure the hot water test at 125° F for 24 hours without cracking or blowing. *Chemical tests.* The state engineer may cause chemical tests of cement to be made and may reject any cement which, in his judgment, is not suited to the purpose.

34 **Initial set.** Neat cement shall not set to support $\frac{1}{4}$ lb weight on $\frac{1}{12}$ inch wire in less than 15 minutes for natural cement and 25 minutes for Portland cement.

35 **Required strength — American Portland cement.** Briquets of neat cement mixed three minutes, put in the molds with thumbs and trowel, and kept at a temperature of 65° to 70° for one day in moist air and six days in water shall show a least average tensile strength of 400 lb per square inch.

Briquets of three parts by weight of standard crushed quartz and one part by weight of Portland cement, mixed in the same manner and kept seven days under the same conditions, shall show a least average tensile strength of 125 lb per square inch.

Briquets of three parts by weight of standard crushed quartz and one part by weight of Portland cement, mixed in the same manner and kept 28 days under the same conditions, shall show a least average tensile strength of 220 lb per square inch.

36 **Required strength — American natural cement.** Briquets of neat natural cement mixed three minutes, put in the molds with thumbs and trowel and kept at a temperature of 65° to 70° for two hours in moist air and 22 hours in water shall show a least average tensile strength of 60 lb per square inch.

Briquets of natural cement and standard crushed quartz in equal parts, by weight, mixed and handled in the same manner and kept at the same temperature for one day in moist air and six days in water, shall show a least average tensile strength of 65 lb per square inch.

Briquets similar to those last described and kept 28 days under the same conditions, shall show a least average tensile strength of 150 lb per square inch.

37 **Standard crushed quartz.** The standard crushed quartz used in the tests shall pass a sieve of 400 meshes per square inch and shall stop on a sieve of 900 meshes per square inch.

Methods of testing

In all the natural cements tested prior to July 1, 1900, the briquets were placed for two hours in air, in place of the usual 24 hours, while the neat Portlands were given a two day test for tensile strength. Since that date practice has been changed, in regard to the natural cements, to conform to the standard, while the Portlands, when tested neat, are usually given a one day test.

Crushed quartz was used in all the mortar tests on both natural and Portland cements, that have been tabulated in this paper, though in 1897 a few additional tests were made with natural sand. These have been omitted, however, as being too few in number to be of much value for comparison.

The boiling test is used on every new brand of cement submitted; and at frequent intervals on all brands.

The machine used is the Fairbanks 1000 lb automatic, with hand molded briquets. It will be noted that though a neat test is required by the specifications for Portlands, it has been made in comparatively few cases. This is in accord with the present trend of engineering practice. It would seem desirable, however, that tests should be made with mortar briquets at longer time periods than those given. Tests at three months and a year on a few briquets from each lot would seem to be of sufficient value to pay for the extra trouble incurred in carrying them out. They would not, it is true, be of any service in deciding whether any particular lot should be accepted or not, but they would certainly give information regarding the staying qualities of each brand, which would be of use in decisions regarding future shipments of that brand.

Another test which it would seem might be profitably introduced, is the determination of the specific gravity of the cements. While there are undoubtedly good Portlands which at times fail to attain a specific gravity of 3.10, and while natural cements and slag cements may occasionally reach that figure, the test is still a good rough means of discriminating the two classes. That such a method of discrimination is not absolutely unnecessary, is shown by the fact that several brands, submitted as Portlands, behaved in a manner which made it probable that they were really natural cements, more or less carefully treated. The physical properties and methods of manufacture of such doubtful mixtures seem to be of some interest, and I hope soon to discuss them more fully in another place. I am not alluding here to the "improved" cements, made by some manufacturers of natural cements, and sold entirely on their merits, but to so called Portlands manufactured in much the same manner as the *grappier* class described by Le Chatelier.

Certain brands occasionally (and others habitually) attain in seven days a strength which enables them to pass both the seven day and 28 day requirements, even though the actual increase in strength during the additional three weeks may be slight. In some extreme cases, indeed, cements have actually shown less strength at 28 days than at seven days. Whether this condition

Portland cements 1898

BRAND	LOCALITY	TESTS	SAMPLES	FINENESS		SET		TENSILE STRENGTH Mortar briquets 1 cemen : 3 sand	
				% passing 50 mesh	% passing 100 mesh	Initial	Hard	Seven days	28 days
Alpha	Alpha N. J.	7	72	99¾	91½	24	78	206	312
Atlas	Northampton Pa.	19	181	99½	93	31	71	191	307
Columbia	Egypt Pa.	34	477	99⅗	93½	27	61	168	248
Commercial	Coplay Pa.	61	1 009	99⅝	93¾	34	89	174	259
Egypt (Giant)	Fgypt Pa.	1	3	98⅛	92½	25	40	169	236
Empire	Warner N. Y	75	1 371	99¼	9[illegible]⅕	34	87	148	235
Flint	"	10	103	99½	93⅝	37	86	154	262
Genesee	Perkinsville N. Y	42	887	99⅝	9[illegible]¼	37	96	178	273
Giant	Jordan N. Y.	29	323	99¾	94	39	80	161	251
Iron Clad	Glens Falls N. Y.	7	88	99⅞	94¼	27	81	189	277
Saylor's	Coplay Pa.	1	3	99	90	67	312	160	157
Star	Siegfrieds Bridge Pa.	4	52	99	93¾	......	......	141	218
Stettin Greston	Stettin. Germany	1	30	97½	85	58	208	193	270
Victor[a]	Glens Falls N. Y.	62	1 031	100	96	41	89	184	272
Vulcanite	Vulcanite N. J	1	1[b]	100	97½	30	110	187	291

[a] Sand cement.

The tests of the natural cements are of considerably less value, as they are based on a much smaller number of samples. The diagrams show very well the fine grinding practised in the Rosendale region. Pl. 94 shows the abnormally high tensile strength for cements of that class obtained during 1900 from the natural cements manufactured in Erie co., N. Y.

Portland cements 1899

BRAND	LOCALITY	TESTS	SAMPLES	FINENESS		SET		TENSILE STRENGTH Mortar briquets 1 cement: 3 sand	
				% passing 50 mesh	% passing 100 mesh	Initial	Hard	Seven days	28 days
Alpha	Alpha N. J	5	21	99¾	96½	113	157	215	304
Anchor Stettin	Stettin, Germany	3	13	100	98	71	156	177	241
Atlas	Northampton Pa	10	74	99¾	96½	41	87	181	275
Columbia	Egypt Pa	10	124	99	93⅘	12	28	145	226
Empire	Warner N. Y	6	73	100	96⅘	38	93	145	241
Excelsior		1	1⁵	100	96¾	180	260	227	350
Flint	Warner N. Y	2	18	100	99	40	62	141	224
Genesee	Perkinsville N. Y	17	115	99⅗	95½	28	51	148	243
Giant	Egypt Pa., Jordan N. Y	6	46	99¼	95½	24	55	167	264
Iron Clad	Glens Falls N. Y	10	139	100	98	45	94	207	311
Lehigh	Ormrod Pa	3	20	100	95¼	70	186	210	336
Saylor's	Coplay Pa	1	10	100	98¼	65	190	130	247
Star	Siegfrieds Bridge Pa	1	4	100	99	28	62	134	264
Victor[a]	Glens Falls N. Y	2	13	100	100	60	158	178	264

[a] Sand cement.

Natural cements 1899

BRAND	LOCALITY	TESTS	SAMPLES	FINENESS		SET		TENSILE STRENGTH Mortar briquets 1 cement: 3 sand	
				% passing 50 mesh	% passing 100 mesh	Initial	Hard	Seven days	28 days
Beach's	Binnewater N. Y.	4	32	95¾	91	35	64	74	175
Brooklyn Bridge	Rosendale N. Y.	1	1^5	96¾	93¾	35	63	94	222
Commercial Rosendale	Coplay Pa.	1	6	92	81¾	30	45	61	181
Helderberg Rosendale	Howe Cave N. Y.	2	6	90	82	16	31	71	147
Norton's	Binnewater N. Y.	2	6	97	93½	24	38	74	178
Union Akron	Akron N. Y.	1	12	95½	90½	30	53	86	225
Union Rosendale		1	15	98	91½	5	10	146	271

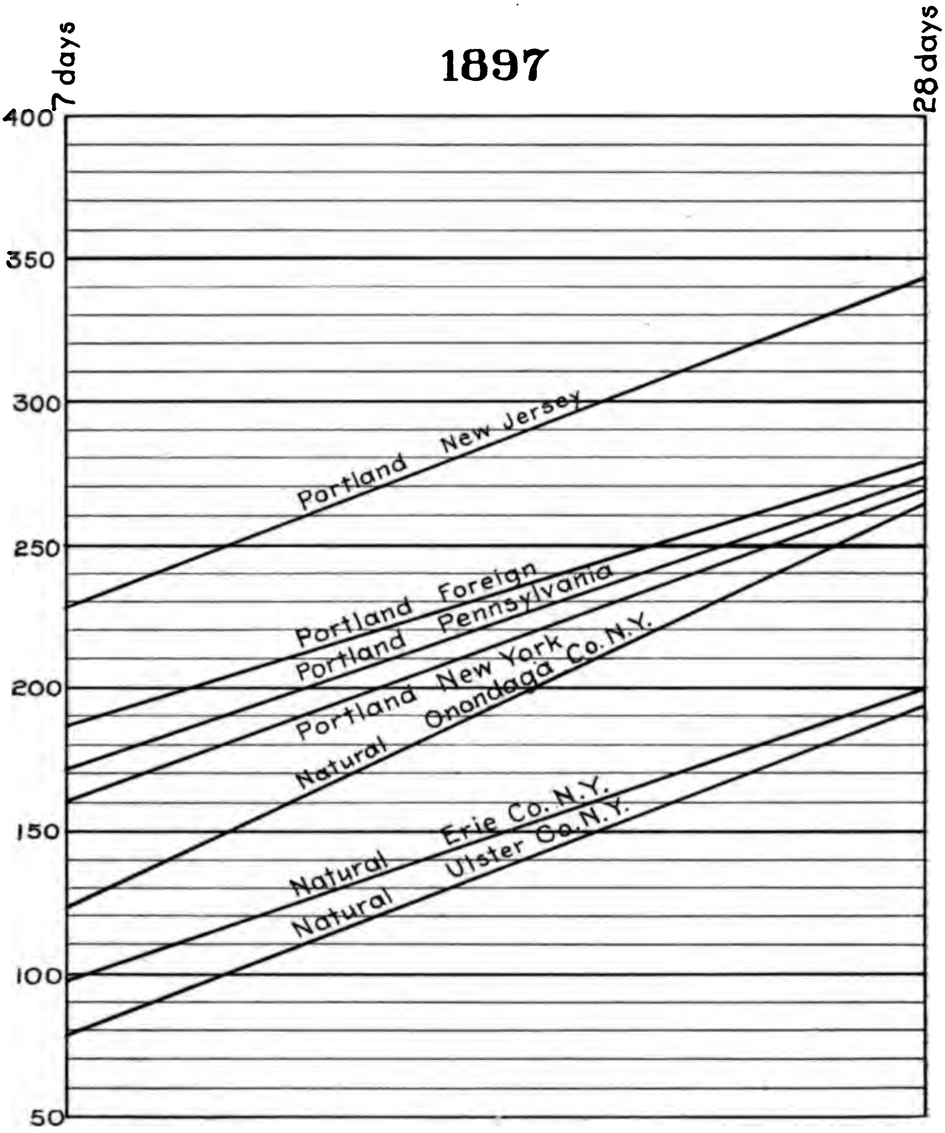
Portland cements 1900

BRAND	LOCALITY	TESTS	SAMPLES	FINENESS		SET		TENSILE STRENG Mortar briquets 1 cement: 3 sand	
				% passing 50 mesh	% passing 100 mesh	Initial	Hard	Seven days	28 days
Alpha	Alpha N. J	5	28	100	97⅓	36	99	218	313
Ajax		4	9	99½	95	38	110	167	269
Atlas	Northampton Pa	19	215	99¾	95⅝	35	95	199	299
Catskill	Smiths Landing N. Y	1	6	100	98¼	25	230	183	329
Commercial	Coplay Pa	3	21	100	96	23	59	141	246
Dragon	Siegfrieds Bridge Pa	4	31	99¾	96⅓	83	177	263	346
Empire	Warner N. Y	4	48	99¼	95⅞	38	101	160	268
Genesee	Perkinsville N. Y	24	227	99¾	94⅓	31	82	163	260
Giant	Egypt Pa	6	33	99	92¾	76	150	191	315
Helderberg	Howe Cave N. Y	4	33	100	99⅞	46	87	273	392
Iron Clad	Glens Falls N. Y	3	59	100	98¾	59	145	329	358
Keystone	Coplay Pa	1	2	100	98¼	75	240	136	205
Lehigh	Ormrod Pa	7	82	99¾	91⅔	93	181	214	323
Nazareth	Nazareth Pa	2	72	100	98⅝	38	100	286	383
Paragon		3	14	99¾	96⅔	44	119	137	231
Vulcanite	Vulcanite N. J	8	349	99¾	95⅓	70	185	286	370
Whitehall	Cementon Pa	5	94	100	97¾	45	134	302	367

Natural cements 1900

BRAND	LOCALITY	TESTS	SAMPLES	FINENESS		SET		TENSILE STRENGTH Mortar briquets 1 cement: 1 sand	
				% passing 50 mesh	% passing 100 mesh	Initial	Hard	Seven days	28 days
Akron natural	Akron N. Y.	2	16	95½	84⅜	24	44	169	370
Beach's	Binnewater N. Y.	1	1	94⅜	85¾	50	75	96	210
Brooklyn Bridge	Rosendale N. Y.	2	33	95⅞	86⅜	49	85	75	189
Buffalo	Buffalo N. Y.	3	40	99⅝	92	10	15	227	413
Helderberg	Howe Cave N. Y.	10	103	92⅝	85¼	24	48	122	240
Hoffman	Binnewater N. Y.	4	45	97¼	92	38	70	75	211
Newark	Whiteport N. Y.	7	33	92¾	84	30	58	67	222
New York	....	1	15	95¼	87	50	85	70	189
Norton's	Binnewater N. Y.	8	56	97	93	44	88	71	206
Union Rosendale	....	4	34	97⅝	92⅝	10	15	104	196

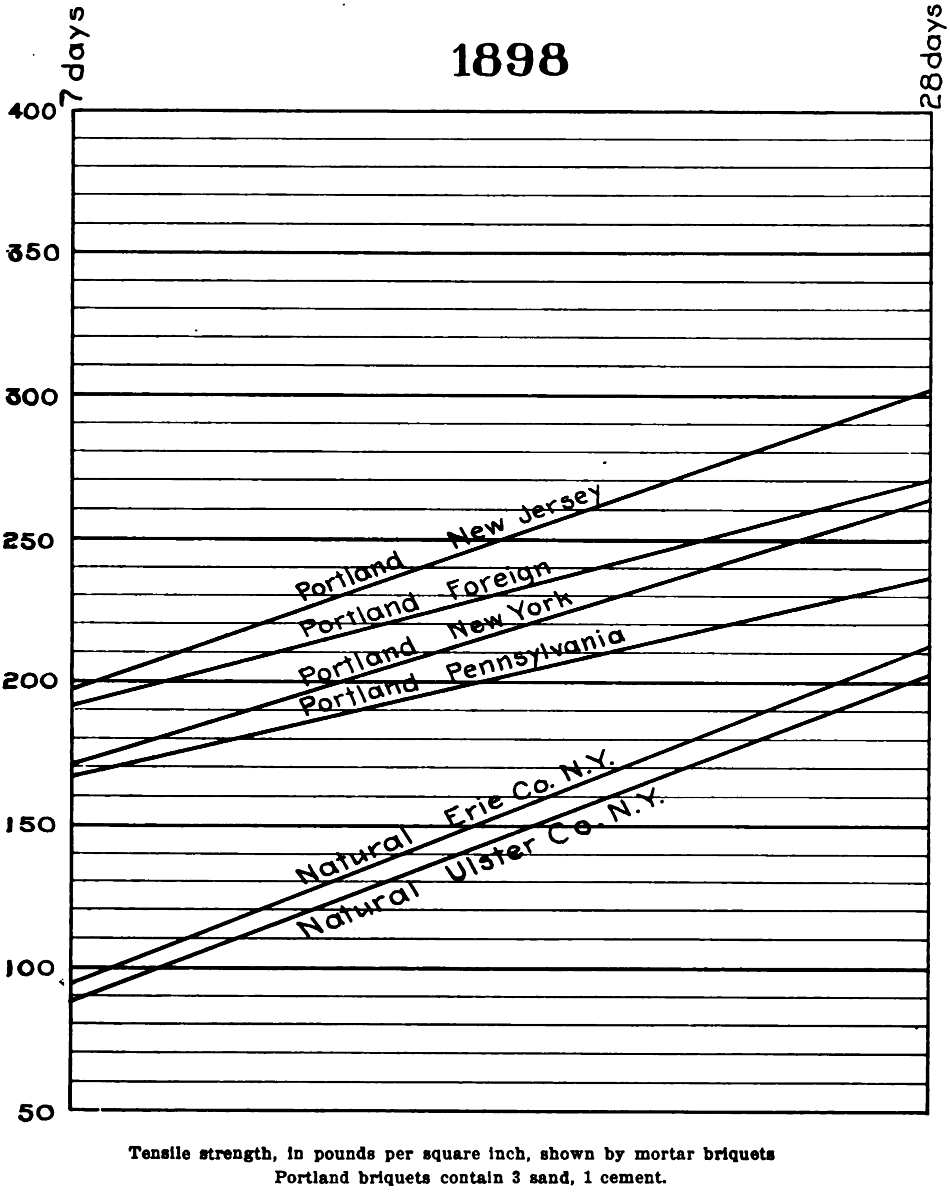
Plate 91



Tensile strength, in pounds per square inch, shown by mortar briquets
Portland briquets contain 3 sand, 1 cement.
Natural briquets contain 1 sand, 1 cement.

RESULTS OF TESTS FOR TENSILE STRENGTH

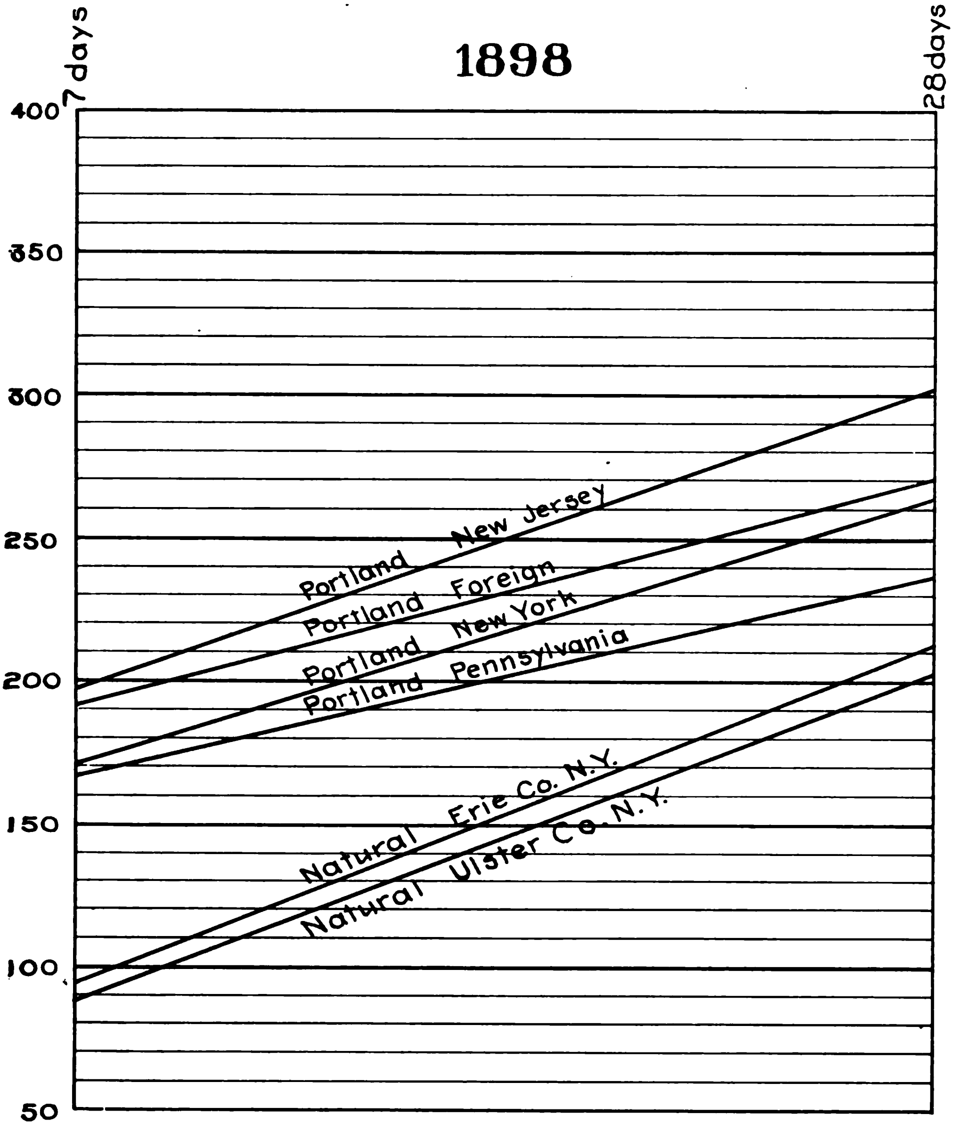
Plate 92



Tensile strength, in pounds per square inch, shown by mortar briquets
Portland briquets contain 3 sand, 1 cement.
Natural briquets contain 1 sand, 1 cement.

RESULTS OF TESTS FOR TENSILE STRENGTH

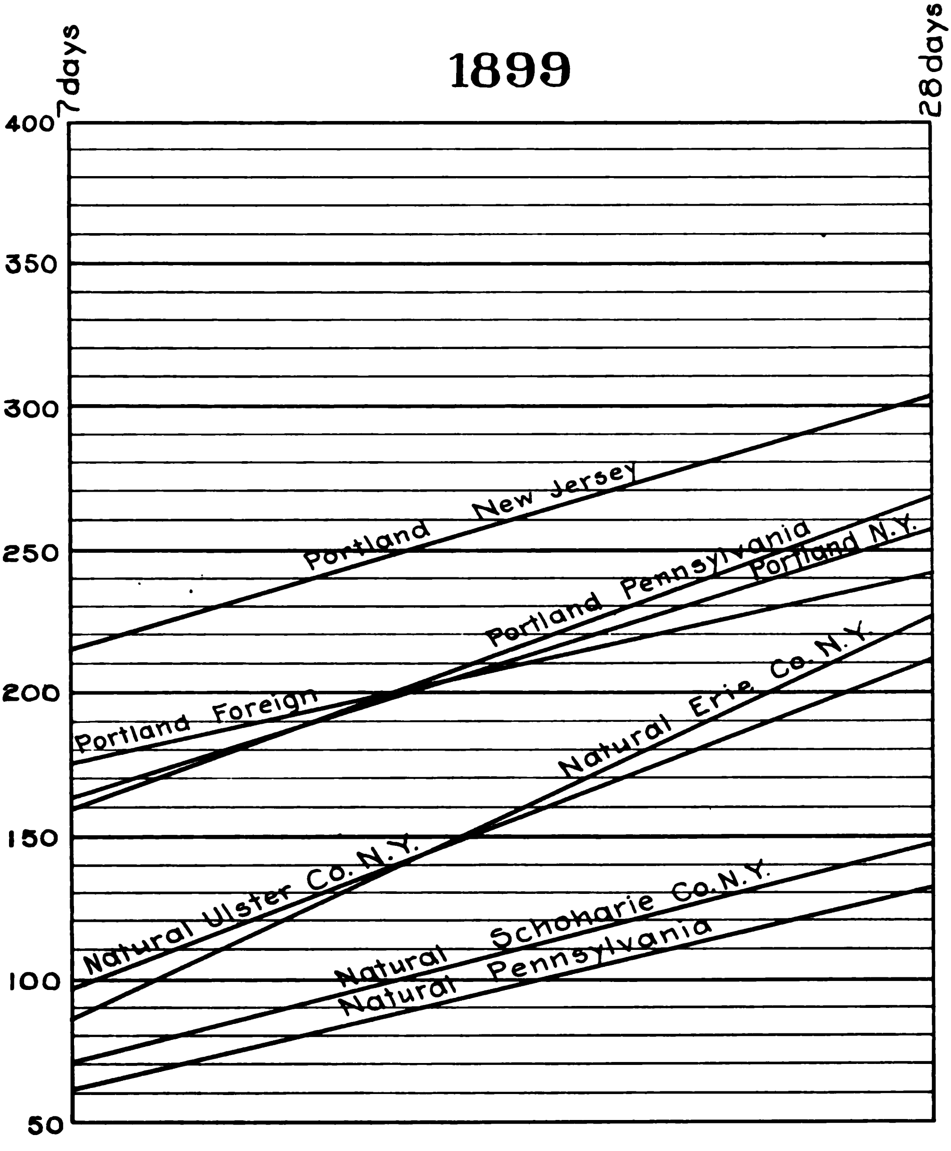
Plate 92



Tensile strength, in pounds per square inch, shown by mortar briquets
Portland briquets contain 3 sand, 1 cement.
Natural briquets contain 1 sand, 1 cement.

RESULTS OF TESTS FOR TENSILE STRENGTH

Plate 93

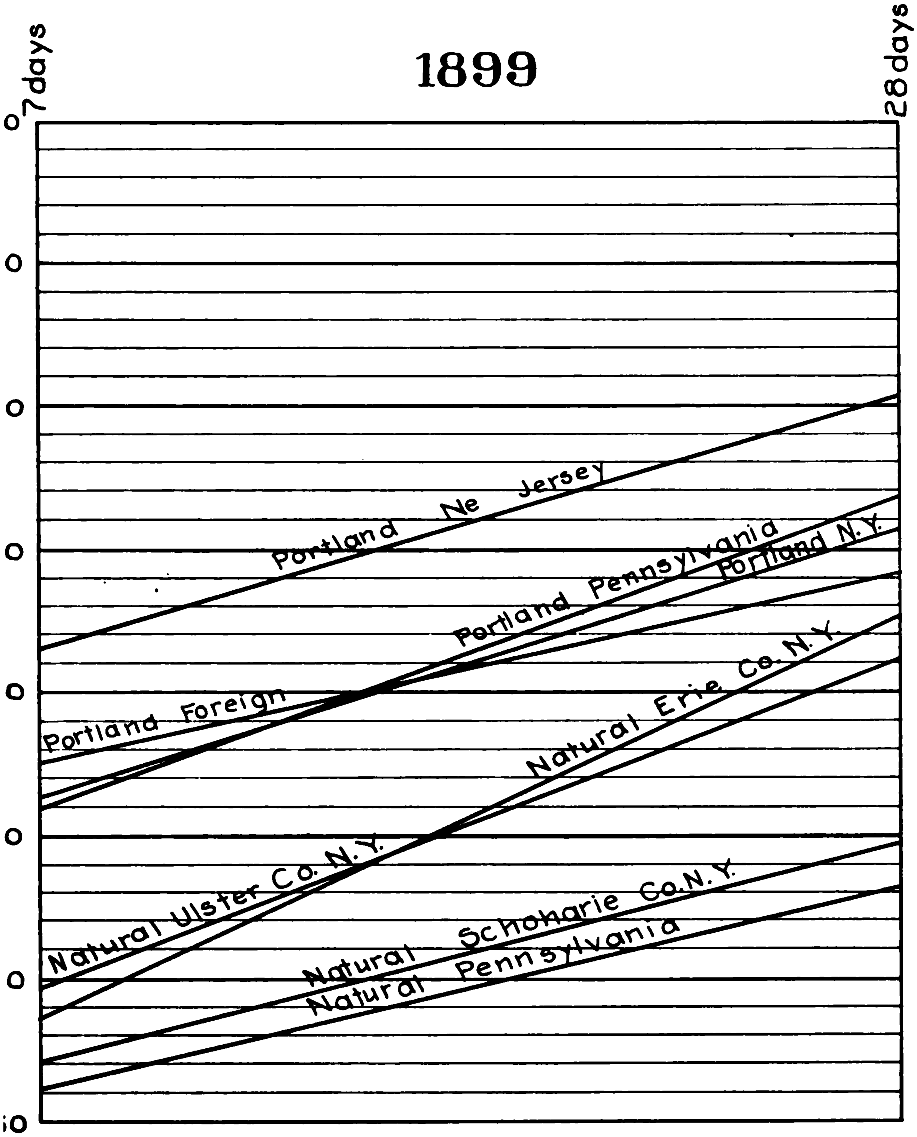


Tensile strength, in pounds per square inch, shown by mortar briquets
Portland briquets contain 3 sand, 1 cement.
Natural briquets contain 1 sand, 1 cement

RESULTS OF TESTS FOR TENSILE STRENGTH

Plate 93

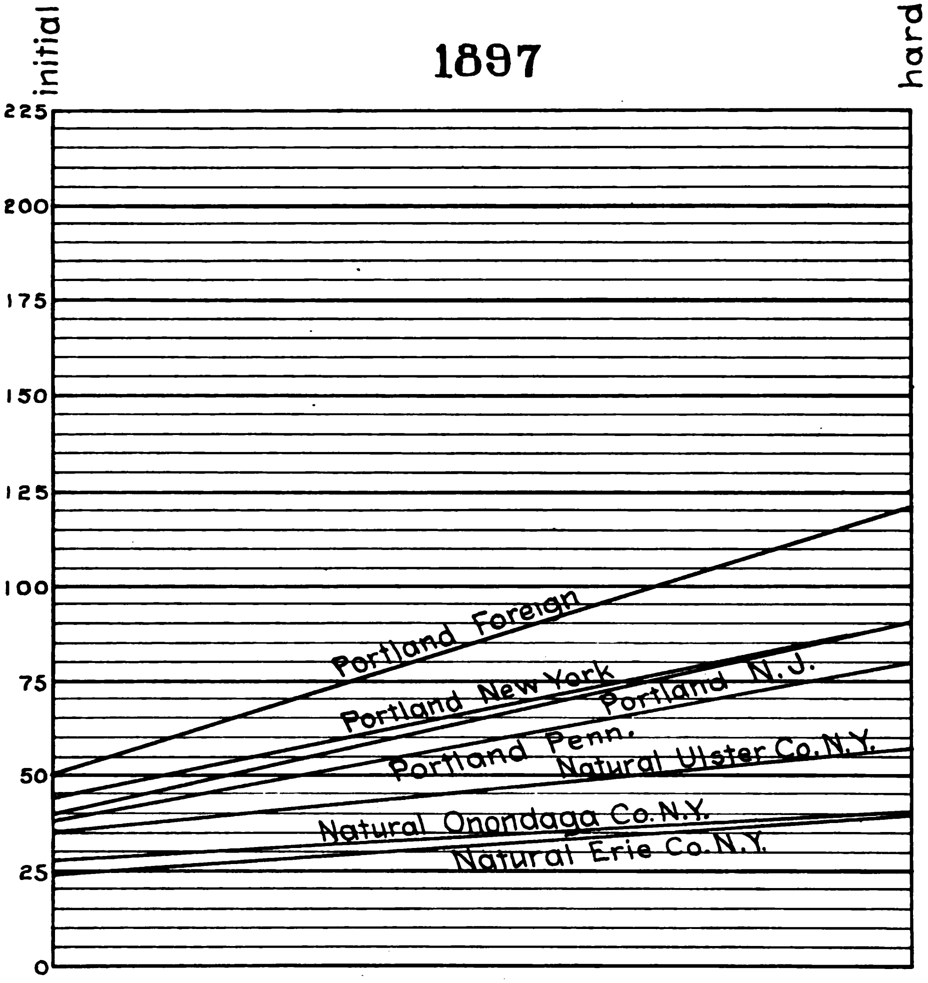
1899



Tensile strength, in pounds per square inch, shown by mortar briquets
Portland briquets contain 3 sand, 1 cement.
Natural briquets contain 1 sand, 1 cement

RESULTS OF TESTS FOR TENSILE STRENGTH

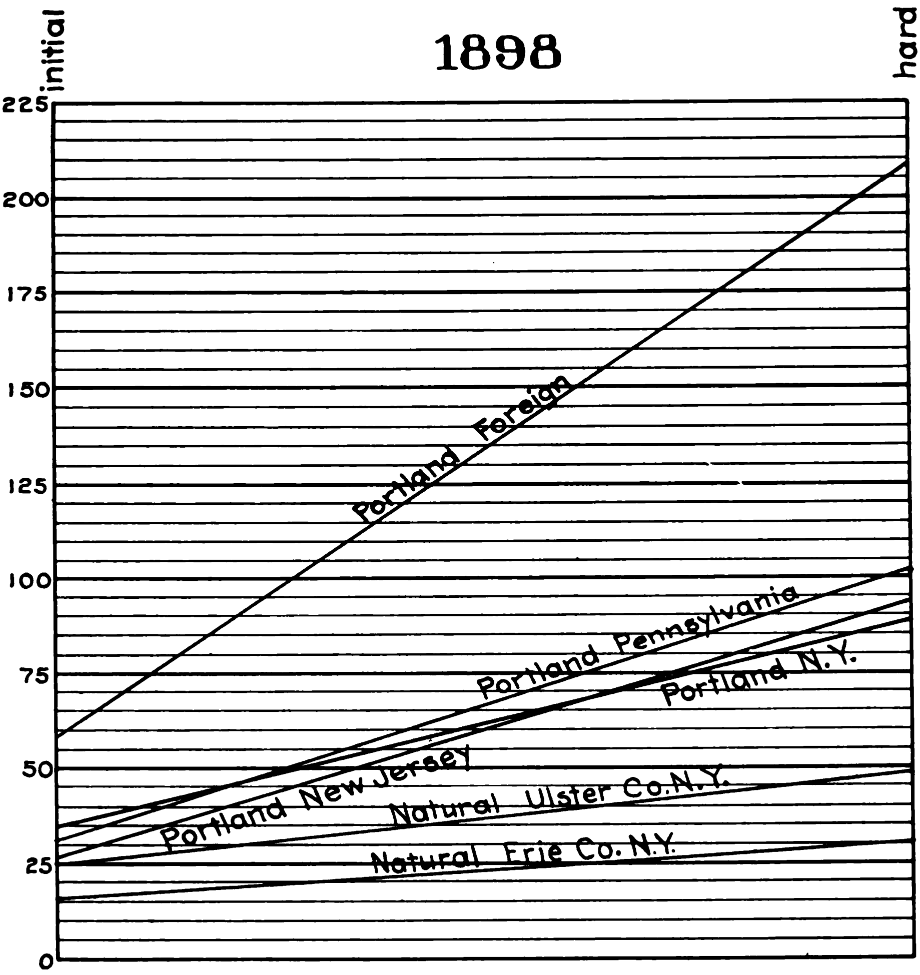
Plate 95



Time of setting shown in minutes

RESULTS OF TESTS FOR TIME OF SETTING

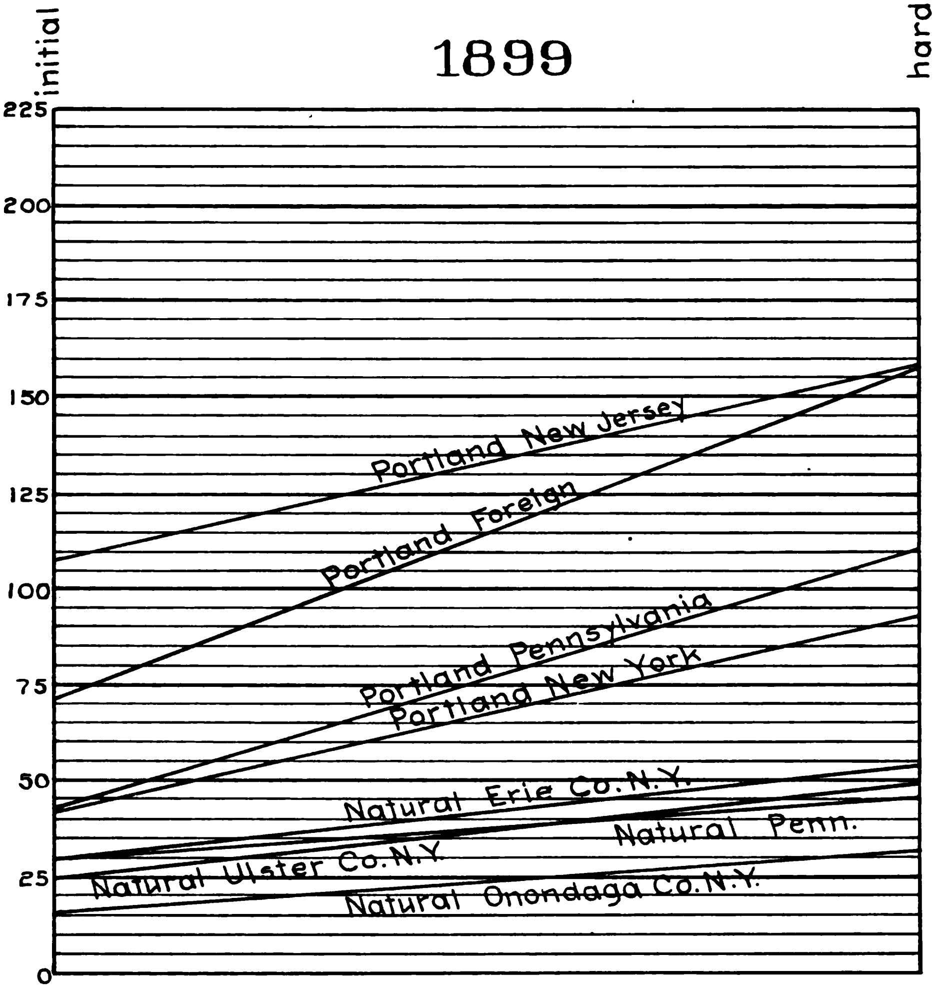
Plate 96



Time of setting shown in minutes

RESULTS OF TESTS FOR TIME OF SETTING

Plate 97



Time of setting shown in minutes

RESULTS OF TESTS FOR TIME OF SETTING

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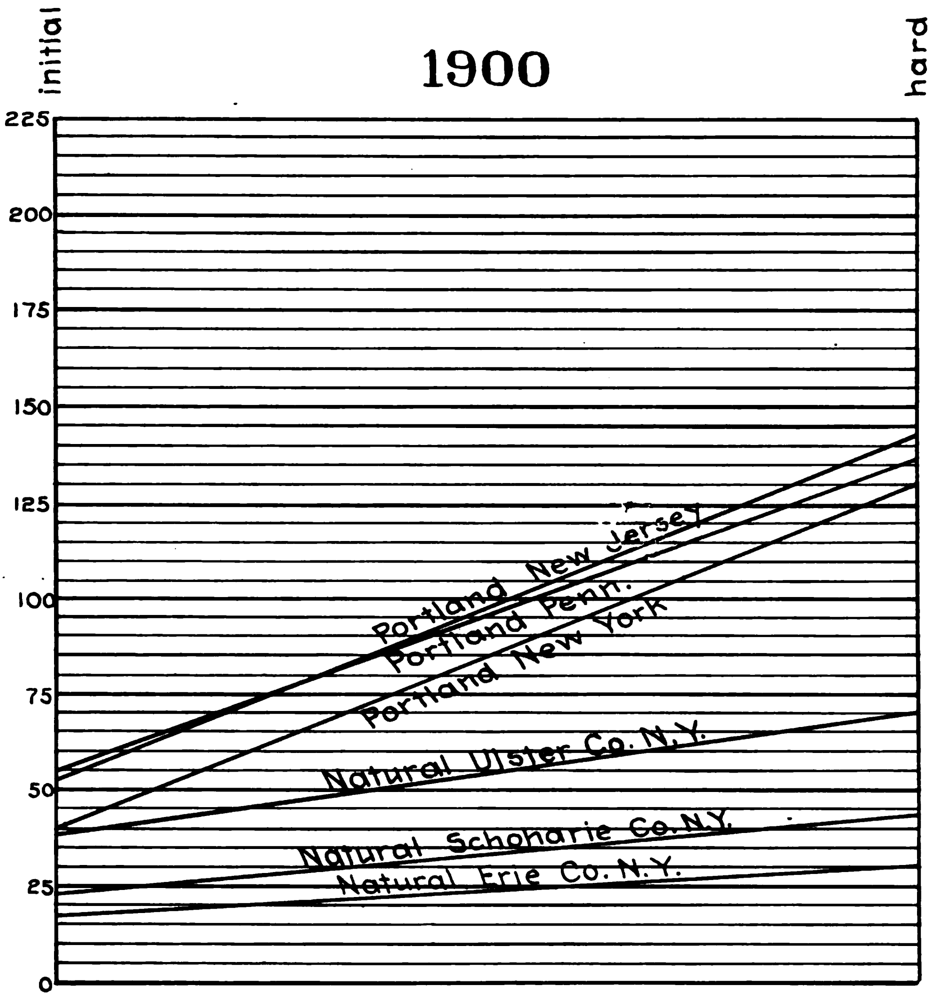
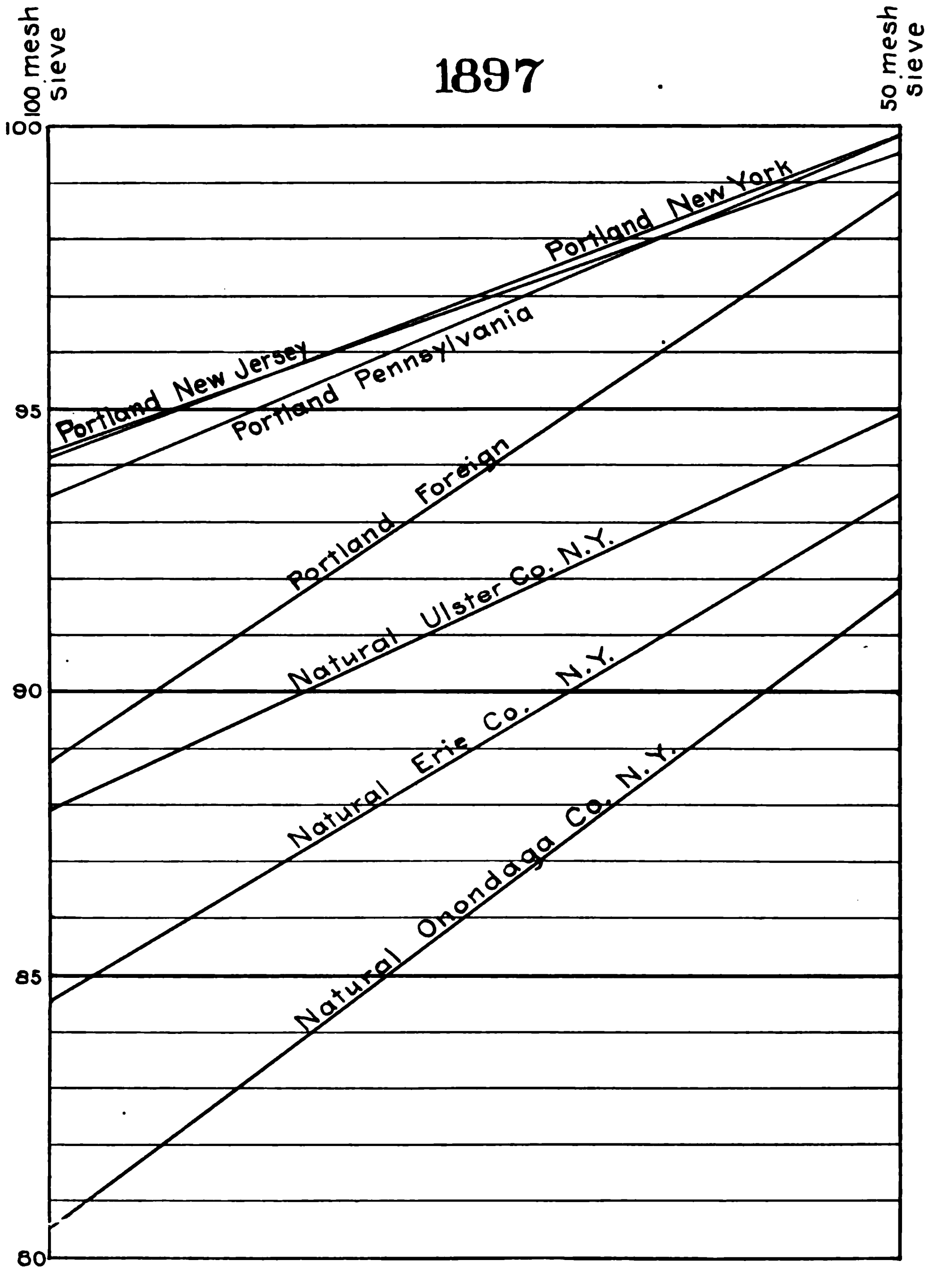
ASTOR, LENOX AND
TILDEN FOUNDATIONS

Plate 98



Time of setting shown in minutes

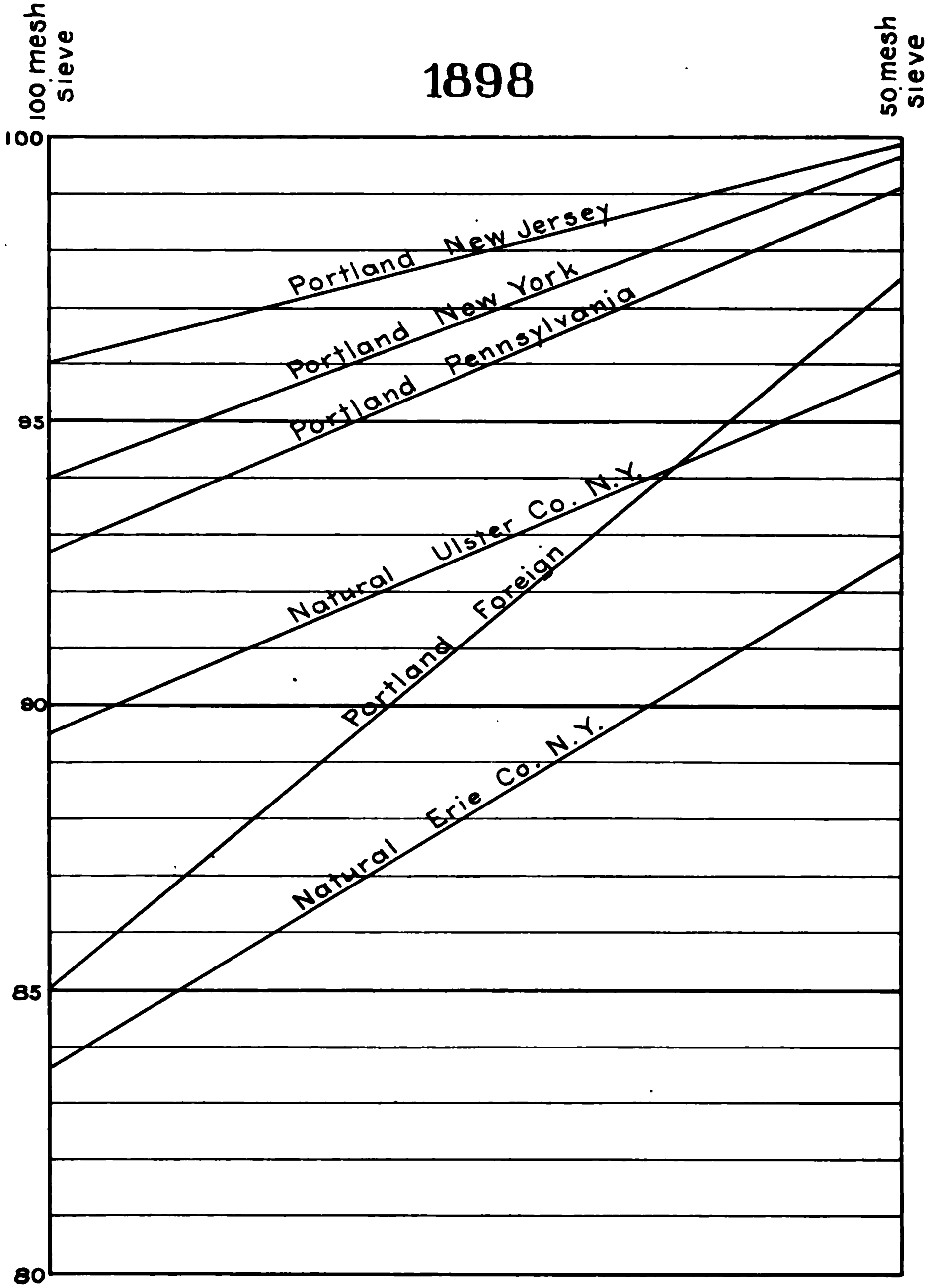
RESULTS OF TESTS FOR TIME OF SETTING



Fineness of cements submitted: shown in percentages passing 100 mesh and 50 mesh sieves

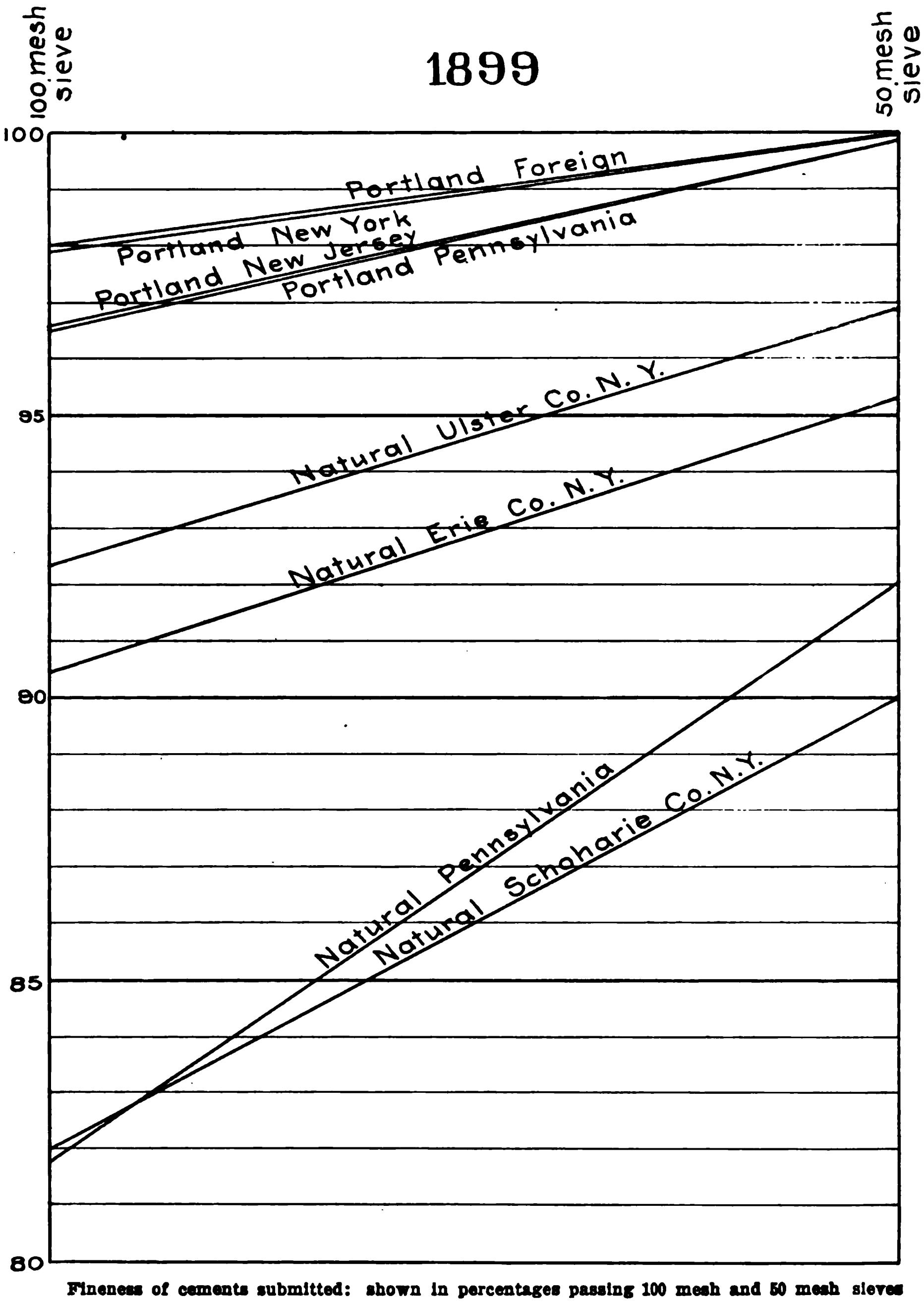
RESULTS OF TESTS FOR FINENESS

Plate 100



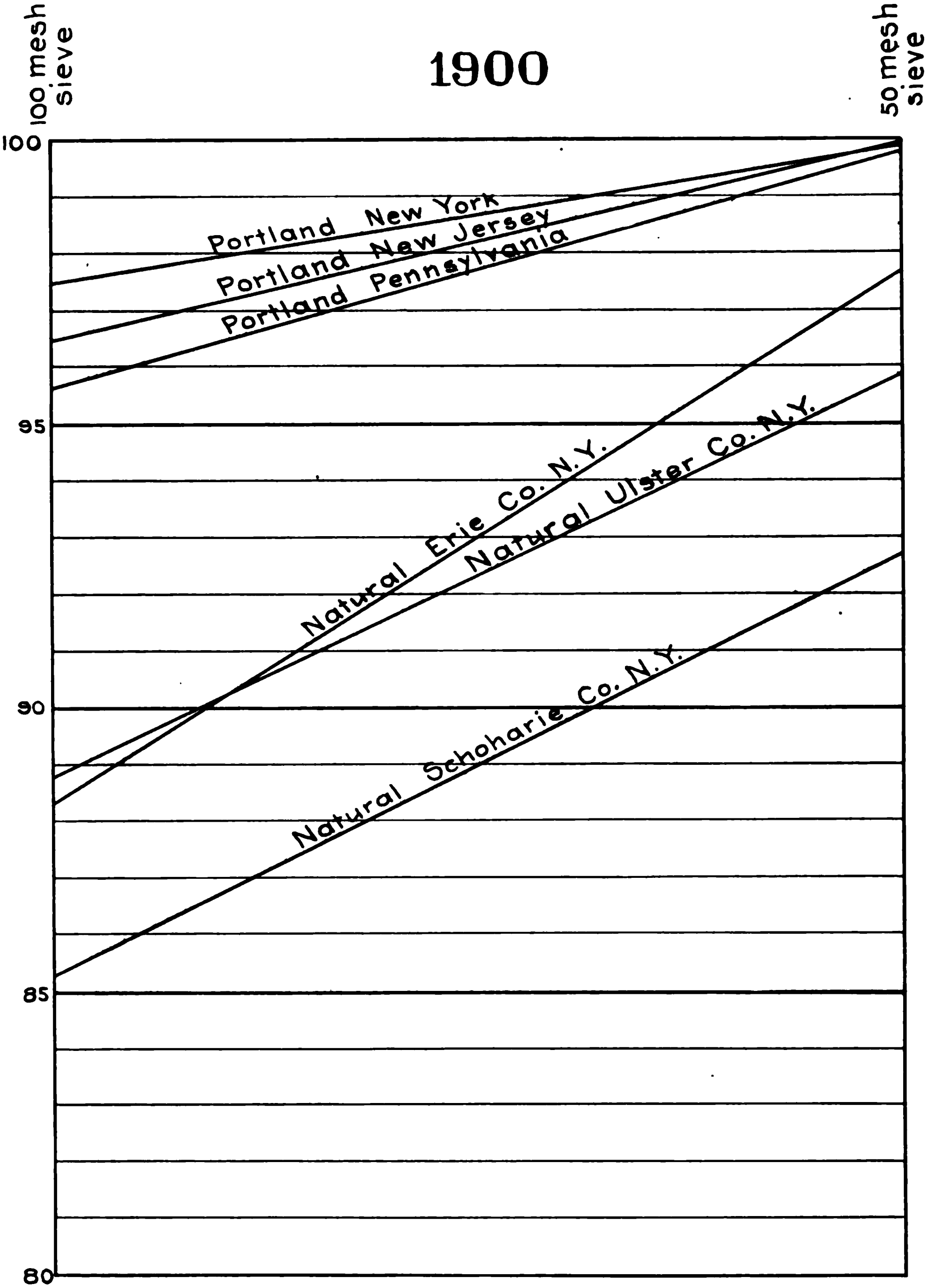
Fineness of cements submitted: shown in percentages passing 100 mesh and 50 mesh sieves
RESULTS OF TESTS FOR FINENESS

Plate 101



Fineness of cements submitted: shown in percentages passing 100 mesh and 50 mesh sieves

RESULTS OF TESTS FOR FINENESS



Fineness of cements submitted: shown in percentages passing 100 mesh and 50 mesh sieves

RESULTS OF TESTS FOR FINENESS

Appendix D

KEY TO THE TABLES OF LIMESTONE ANALYSES

BY EDWIN C. ECKEL C. E.

The limestone analyses which follow this section were collected by Dr Heinrich Ries. They have been carefully rearranged and revised in this office. Each analysis has been compared with its original published record, and the tables are, it is believed, entirely reliable.

At the suggestion of Dr F. J. H. Merrill the present writer has prepared a key to the tables of analyses to facilitate reference. This key is based on composition, and will be of use in determining the areas from which limestones of any given composition may be obtained. A table has been prepared in which its results are summed up, classified both by composition and by states.

For most commercial uses the components of greatest interest in a limestone are its lime carbonate, magnesium carbonate, and silica plus alumina. The limestones whose analyses are given in the following tables have, therefore, been first divided into four primary groups, the grouping being based on the percentages of lime carbonate in the rock. Each of these primary groups is then subdivided, according to the percentages of magnesium carbonate present. Finally, the secondary groups thus obtained are again divided according to the percentages of silica and alumina contained in the rocks. As shown in the summary below, 20 groups are thus formed.

KEY TO GROUPING

Calcium carbonate 95% or over	Group 1
Calcium carbonate 85% to 95%	
Magnesium carbonate less than 5%	Group 2
Magnesium carbonate over 5%	Group 3

- Calcium carbonate 60% to 85%
  - Magnesium carbonate less than 5%
    - Silica and alumina less than 10%.... ..... Group 4
    - 10% to 20% .... Group 5
    - more than 20% .... Group 6
  - Magnesium carbonate 5% to 20%
    - Silica and alumina less than 10%.......... Group 7
    - 10% to 20% .... Group 8
    - more than 20% .... Group 9
  - Magnesium carbonate more than 20%
    - Silica and alumina less than 10%......... Group 10
    - 10% to 20% .... Group 11
- Calcium carbonate less than 60%
  - Magnesium carbonate less than 5%
    - Silica and alumina less than 10%......... Group 12
    - 10% to 20% .... Group 13
    - more than 20% .... Group 14
  - Magnesium carbonate 10% to 20%
    - Silica and alumina less than 10%......... Group 15
    - 10% to 20% .... Group 16
    - more than 20% .... Group 17
  - Magnesium carbonate more than 20%
    - Silica and alumina less than 10%......... Group 18
    - 10% to 20% .... Group 19
    - more than 20% .... Group 20

If, now, limestone of a particular composition be sought, its place in the tables can be readily ascertained. The first step is to find from the "Key to grouping" above, in what group limestones of the desired composition will fall. This ascertained, the preliminary scheme *immediately* following this appendix will show in what states limestones of that group may be found, the limestones being designated by numbers corresponding to those used in the regular "Tables of limestone analyses" which follow the preliminary scheme.

KEY TO TABLES OF

STATE	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5
Alabama	1, 2, 4, 8, 11, 12, 15, 16	5	......	......	10
Arkansas	38	29, 30	......	......	......
California	......	......	......	......	......
Colorado	......	......	......	......	......
Connecticut	......	......	......	......	......
Georgia	95, 99, 102	101, 104	......	105	......
Illinois	106	119	107	......	......
Indiana	134, 136, 137, 141, 142, 151-57, 164-71, 187-90	124, 129-32, 135, 138, 143, 146, 148, 149, 177	145, 158, 159, 160, 162, 172, 173, 174, 175, 176, 179-82	144, 147, 150, 192	......
Iowa	197, 198	195, 204	199	203	......
Kansas	209, 212, 218, 219, 226, 251-53	207-8, 210, 211, 213, 215, 216, 221, 223-25, 227, 230, 235, 237-40, 247, 256, 258, 259, 261, 262	206, 228, 229	241	214, 217, 236, 242, 248-50, 254, 255, 257, 260
Kentucky	264, 269, 275, 277, 278, 291, 298, 309, 354, 355	263, 274, 285, 286, 297, 299, 304-7, 318, 334, 336, 351, 353, 356, 357	279, 300, 303, 306, 311, 314, 315, 316, 337	287, 348	276, 333, 335, 349
Louisiana	359, 360	......	......	......	......
Maine	361-63	......	......	......	......
Maryland	368-70, 372, 377, 379, 380	366, 371, 373, 378	......	......	......
Massachusetts	381, 384, 386, 387	......	......	......	......
Michigan	390, 400, 401, 408, 409	396	395, 397-98, 402	......	......
Minnesota	......	411	......	......	......
Mississippi	......	......	......	......	......
Missouri	428, 430, 431, 433-40	......	429	......	......
Montana	......	446, 447	441	......	......
Nevada	......	452, 453	......	......	......

LIMESTONE ANALYSES

GROUP 6	GROUP 7	GROUP 8	GROUP 9	GROUP 10	GROUP 11	GROUP 12	GROUP 13	GROUP 14	GROUP 15	GROUP 16	GROUP 17	GROUP 18	GROUP 19	GROUP 20
6	....	....	....	....	....	......	....	....	....	9	....	3, 17	....	....
....	....	....	....	....	....	......	....	19, 20, 37	....	....	......	22, 23, 27, 31, 32, 34, 35	18, 21, 24, 25, 26, 28, 36	....
39	....	....	....	....	....	....	....	....	....	...	.....	40	....	....
42	....	....	....	....	....	....	....	....	....	..	....	41	....	43
....	....	....	....	....	....	....	...	....	....	....	......	88, 90	....	....
....	....	....	...	....	....	....	...	....	....	96	.....	91, 94, 98, 100, 103	93	92
....	....	....	....	....	...	....	...	....	....	....	....	108, 109, 110, 111, 112, 115	113	114 116, 117
....	120-123, 140, 178	....	....	139	133	....	...	....	....	125	161, 183, 184, 186	120, 126, 127, 128, 163, 185, 191, 193	......	183, 161, 312
....	....	....	205	194	....	202	...	....	200-1	....	....	196	....	....
....	....	222	....	...	220, 245	....	....	....	....	....	....	243 244, 246	......	....
....	265, 267, 270, 271, 290, 308, 339, 347	206, 341	348	272, 305 338, 340	....	....	310	280, 326	278, 332,	267, 318, 329	262, 261, 319-22, 327-30	282, 288, 289, 317, 322, 323, 324, 325, 344, 345, 358	268, 283, 284, 295, 331, 346	302, 320, 321, 350, 352
....	....	....	....	....	....	....	....	....	....	....	.....	....	....	....
....	....	..	..	....	....	....	....	....	....	....	.....	....	....	....
....	367	....	....	....	...	....	..	....	376	364	.....	365, 374-75	....	....
....	....	....	....	....	....	....	....	....	388	....	....	389	....	....
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....	905	....	....	....	....	......	..	....	....	...	......	....	......	....
....	906	...	....	..	....	....	....	......	....	....	......	....	......	....
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ANALYSES OF LIMESTONES

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Alabama									
1	Blount	Blount Springs	.5	.4		99.1	.....	.....	.....	.....
2	Calhoun	Anniston	.74	.36		98.76	trace	.....	.....	.....
3	"	Morrisville	3.24	.17	.17	*a*29.58	*b*20.84	45.54	.....	.....
4	Colbert	Sheffield	.5	.....	1.45	*a*54.2	*b*1.23	42.61	.....	.....
5	Conecuh	Evergreen	2.75	1.09	1.64	*a*52.36	*b*.11	41.44	.....	.....
6	Dallas	Cahaba	19.64	4.72	4.63	66.37	.79	.....	.....	.....
7	DeKalb	Fort Payne L	1 69	.....	.....	*a*96.12	*b*.11	.....	.....	.....
8	Franklin	Russellville	.9	.7	.....	97	1.4	.....	.....	.....
9	Lowndes	Benton	19 74	7.74	3.93	*a*30.77	*b*2.45	26.39	.....	.....
10	Marengo	Demopolis	12.13	4.17	3 28	75.07	*b*.92	.....	.....	.....
11	Shelby	Longview	.....	.13		99.11	.75	.....	.39	.....
12	"	"	.....	trace		99.16	.75	.....	.15	.....
13	"	" L	.....	.26		*a*98.44	*b*.98	.....	.18	.....
14	"	" L	.....	21		*a*97.3	.....	.....	.37	.....
15	"	Shelby	.23	.21	trace	99.13	.12	.....	.....	.....
16	"	Siluria	.10	.63		98 91	.58	.....	.....	.....
17	Talledaga	Stanley	.....	1.47		55.95	40.9	.....	1.34	.....
	Arkansas									
18	Carroll	Beaver	8.66	4.77		48.48	33 58	.....	.....	.....
19	Clark	Okolona	.....	7.99	7.42	22.04	2	.....	& SiO_2 53.07	.....
20	"	Boseman place	.....	6.735	4.65	35.95	*b*1.306	.....	& SiO_2 44 04	.....
21	"	Leatherwood switch	8.65	4.72		47.91	39.23	.....	.....	.....
22	"	"	.....	.....	.....	49.53	40	.....	.....	.....
23	"	Waldons	.....	.....	.....	49.47	40.85	.....	.....	.....
24	Desha	White River	13.52	.89		48.23	38.36	.....	.....	.....
25	Eureka Springs	Eureka Springs	14.71	.....	.....	47.43	35.76	.....	.....	.....
26	"	3 m. s. e. of Yellville	12.07	.....	.....	48.53	37.91	.....	.....	.....
27	Lawrence	Hoppe mine	.....	.....	.....	53.998	35.059	.....	6.701	.....
28	"	Koch mine	.....	& Mn 1.482		10.075	32.487	4.985	10.935	.....
29	Little River	Rocky Comfort	.....	1.25		88.48	*b*tr.	.....	& SiO_2 9.77	.....
30	"	White Cliffs	.....	1.41		94 18	1.37	.....	& SiO_2 3.49	.....
31	Marion	Wood's mine	.....	& Mn 3.023		50.041	42.317	.....	3 191	.....
32	Newton	Mt Hersey	8.01	1.21		56.58	34.69	.....	.....	.....
33	"	20 n. 18 w. s. 35	.....	.....	.....	.....	36.75	.....	.....	.....
34	"	19 n. 17 w. s. 17	.....	.....	.....	49.89	37.21	.....	.....	.....
35	"	19 n. 17 w. s. 7	.....	.....	.....	32.25	24.02	.....	.....	.....
36	"	19 n. 18 w. s. 11	12.76	.....	.....	48.22	37 89	.....	.....	.....

a CaO   *b* MgO

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
1		U. S. geol. sur. 20th rep't, pt 6, p. 354; Dr W. B. Philips, anal.	A. P. Birch quarry
2		U. S. geol. sur. 20th rep't, pt 6, p. 354; W. Mackemson, anal.	Anniston lime works co.
3	FeO .06	U. S. geol. sur. Bul. 168, p. 258	Knox dolomite
4		" 20th rep't, pt 6, p. 354	T. L Fossick
5	SO_3 .018 Alkalis .14	Ala. ind. and sci. soc. 5:44–51	
6	Alkalis .04	" "	
7	SO_3 trace P_2O_5 .01	U. S. geol. sur. 20th rep't, pt 6, p. 354–55; A. D. Brainerd, anal.	Standard lime co.
8		U. S. geol. sur. 20th rep't, pt 6, p. 354–55; J. C. Foster, anal.	Franklin quarry co.
9	SO_3 .85 Alkalis 2.88	Ala. ind. and sci. soc. 5:44-51	
10	Alkalis .09 $Ca_3P_2O_8$ .4	" "	
11		U. S. geol. sur. 20th rep't, pt 6, p. 354–55; E. A. Smith, anal	Longview lime works, no. 1
12		U. S. geol. sur. 20th rep't, pt 6, p. 354–55; E. A. Smith, anal.	" no. 2
13	CO_2 .32	U. S. geol. sur. 20th rep't, pt 6, p. 354-55; W. Stubbs, anal.	"
14		U. S. geol. sur. 20th rep't, pt 6, p. 354–55	"
15	P_2O_5 trace	" "	Shelby iron co.
16		" "	T. L. Fossick
17		U. S. geol. sur. 20th rep't, pt 6, p. 354–55; A. Noble, anal.	J. T. Landt
18	$CaSO_4$ .42	U. S. geol. sur. 20th rep't, pt 6, p. 354–55; Navy dep't, Wash. anal.	Mark Liles
19	Loss on ign. 4.74	Ark. geol. sur. 1888, 2:237	Sandy lime marl
20	SO_3 1.7 P_2O_5 .234	" "	Rich lime marl
21		" 1890, 4:117	
22		" "	
23		" "	
24		" "	18 n. 13 w. section 36
25		" "	
26		" "	
27	$FeCO_3$ 2.25 $ZnCO_3$ 1.98 Alkalis .106	" "	
28	Alkalis .136	" "	
29		" 1888, 2:237	Chalk
30	Loss on ign. .55	" "	Chalk
31	$ZnCO_3$ 1.95 Alkalis .435	" 1890, 4:117	
32		" "	
33		" "	
34		" "	
35		" "	
36		" "	

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Arkansas (*c'd*)									
37	Sevier	Brownstown	....	4.26	4.86	46.73	1.51	......	41.72	......
38	Washington ...	Johnson	......		.17	99.34	....	......	.39	.1
	California									
39	Contra Costa ..	Mt Diablo.	21.19	.39	1.52	*a*35.61	*b*1.39	26.84	....	.76
40	Inyo...........	Near Keeler.........	......	......	.017	*a*31.042	*b*21.791	47 353	....	......
	Colorado									
41	Arapahoe	Denver	......	.54	.11	*a*27.49	*b*18.03	41.4	12.01	.61
42	Garfield	Glenwood Springs...	......	......	.97	*a*40.64	*b*.73	32.73	21.45	......
43	"	" ..	.....	....	.18	*a*15.87	*b*10.6	4.13	47.74	......
44	"	" ..	......	......	.42	*a*46.65	*b*2.64	39.55	6.47	......
45	"	" ..	......	......	....	*a*47.4	*b*4.49	42.15	3.71	......
46	"	" ..	......	......	.26	*a*39.56	*b*8.56	40.52	9.44	.....
47	"	" ..	......	......	.74	*a*26.5	*b*14.86	37.18	17.82	......
48	"	" ..	......	......	.03	*a*32.14	*b*18.72	45.85	1.96	.....
49	"	" ..	......	......	trace	*a*55.17	*b*.21	43.58	.22	......
50	"	" ..	......	......	.14	*a*53.79	*b*.46	42.76	2.27	......
51	"	" ..	......	......	.09	*a*55.49	*b*.24	43.87	.23	......
52	"	" ..	.....	....	....	*a*55.81	*b* trace	43.85	.06	......
53	"	" ..	....	......	.1	*a*55.45	*b* 4	43 84	.22	......
54	"	" ..	.....	....	.03	*a*55.68	*b* trace	43.75	.11	......
55	Jefferson.......	Morrison	......	.53	.38	*a*48 73	*b*2.95	41.71	5.32	.11
56	Lake	Leadville	.21	.27	.21	*a*30.79	*b* .14	46.84	....	.22
57	"	"	.7	.17	.11	*a*30.43	*b*20.78	46 93	....	.04
58	"	"	.27	.04	.22	*a*29.97	*b*21.52	47.39	....	.07
59	"	"	7.76	.11	.1	*a*27.26	*b*20.05	43.79	....	.05
60	"	"	11.84	1.66	1.51	*a*26.6	*b*1 .41	40.01	....	.48
61	Ouray..........	Ouray..............	......	trace	....	97.3	e	...	....	......
62	Park	Fairplay............	......	......	....	*a*53.64	*b*.73	42.93	2.37	.51
63	"	Buckskin gulch.....	17.64	.90	.62	*a*32.23	*b*19.01	25.33	....	2.72
64	"	Mt Silverheels......	......	......	....	*a*55.5	*b*.17	43.82	.51	.....

*a*CaO *b*MgO

THE UNITED STATES (*continued*)

No.	MISCEL-LANEOUS		REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
37	....		Ark. geol. sur. 1888, 2:237..........................	Sandy lime marl
38	....		U. S. geol. sur. 20th rep't, pt 6, p. 358; G. L. Teller, anal.	Crescent white lime co.
39	MnO	3.61	U. S. geol. sur. Bul. 148, p. 275; W. H Melville anal.	
40	....		U. S. census 1890 min. ind. p. 607.................	
41	MnO	.20	U. S. geol sur. Bul. 168, p. 270; L. G. Eakins, anal..	Niobrara limestone
42	FeO	.23	" 148, p. 273; G. Steiger, anal	
43	FeO	.71	" " "	
44	FeO	.35	" " "	
45	FeO	.55	" " "	
46	FeO	.32	" " "	
47	FeO	.57	" " " ...	
48	FeO	.35	" " " ...	
49	....		" " "	
50	....		" " "	
51	....		" " "	
52	....		" " "	
53	FeO	.1	" " "	
54	FeO	.07	" " "	
55	P_2O_5 MnO	.03 .49	" 168, p. 270; L. G. Eakins, anal..	Upper Wyoming limestone
56	FeO Cl Alkalis	.21 .1 .09	" " p. 271, W. F. Hillebrand, anal.	Silver Wave mine
57	FeO MnO Alkalis Cl P_2O_5	.38 .05 .14 .14 .12	U. S. geol. sur. Bul. 168, p. 271, A. Guyard, anal...	Dugan quarry
58	FeO MnO Alkalis P_2O_5 Org.	.13 2 .03 .03 .02	" " " ...	Glass-Pendery mine
59	FeO MnO Alkalis P_2O_5 Cl FeS_2 Org.	.57 .06 .06 .07 .06 trace .07	" " " ...	Montgomery quarry
60	Alkalis FeO	.05 .88	" " p. 271, W. F. Hillebrand, anal.	Carbonate Hill quarry
61	....		Am. inst. min. eng. Trans. 16:580	
62	FeO	.19	U. S. geol. sur. Bul. 148, p. 272; W. F. Hillebrand, anal.	
63	FeO MnO Alkalis P_2O_5 Cl	.18 trace .07 .05 .08	U. S. geol. sur. Bul. 148, p. 272; W. F. Hillebrand. anal.	Serpentinous limestone
64	....		U. S. geol. sur. Bul. 148, p. 272; W. F. Hillebrand, anal.	

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Colorado (*c'd*)									
65	Park	Mt Silverheels.......	.....	....	....	*a*30.19	*b*20.47	46.52	1.98	......
66	Pitkin	....	.....	....	.22	*a*30.66	*b*20.94	47.13	.16	......
67	"	....	.....	....	1.63	*a*31.19	*b*19.69	46.16	.8	......
68	"	....	.....	....	2.1	*a*33.74	*b*16.76	44.94	1.02	......
69	"	....	..	.....	1.88	*a*35.98	*b*8.25	37.35	13.63	......
70	"	....	.....	....	3.34	*a*31.61	*b*18.06	44.7	1.42	......
71	"	....	.....	....	.36	*a*37.28	*b*.54	29.68	31.12	......
72	"	....	.....	....	.88	*a*38.85	*b*9.97	41.47	7.78	......
73	"	Aspen...............	.....	....	.88	*a*31.16	*b*20.64	47.19	.52	......
74	"	"	.....	....	trace	*a*55.81	*b*.16	44.03	.33	......
75	"	"	.....	....	1.31	*a*30.46	*b*20.9	46.92	.84	......
76	Pueblo	Pueblo	76.8	1.71	1.23	*a*49.06	*b*.56	....	....	......
77	Summit	Copper mountain...	.....	....	....	*a*54.23	*b*.21	42.97	2.69	.....
78	"	Pittston tunnel	.....	....	.....	*a*55.24	*b*.24	43.81	.62	......
79	"	Pearl hill............	.....	....	....	*a*28.01	*b*18.33	42.63	10.09	......
80	"	Summit quarry.....	.....	....	....	*a*53.6	*b*1.23	43.65	1.75	......
81	"	....	.....	....	....	*a*55.17	*b*.28	43.76	1.37	......
82	"	Pittston tunnel	.....	....	....	*a*50.88	*b*.7	40.9	7.91	......
83	"	Summit King shaft.	.....	....	.....	*a*28.05	*b*18.15	43.88	6.75	......
84	"	North of Sugar Loaf.	.....	....	....	*a*52.97	*b*.4	42.12	4.42	......
85	"	Searls gulch	.....	....	....	*a*55.58	*b*.37	44.17	.36	......
86	"	Elk mountain	.....	....	....	*a*55.47	*b*.22	43.86	.82	......
87	"	Jacque mountain...	.....	....	....	*a*54.62	*b*.25	43.23	2.04	......
	Connecticut									
88	Litchfield ...	Canaan..............	.08	.25		54.4	45.12	.....	....	......
89	"	" L	.42	....	....	*a*56.57	*b*42.56	.....	....	......
90	"	East Canaan	.....	.2		*a*31.31	*b*21.03	46.98	.48	......
	Georgia									
91	Bartow.........	Cave spring.........	3.5	......	1.5	53.44	41.15	.....	....	......
92	"	Cement	22.1	5.45	1.8	43.5	26	....	....	......
93	"	"	10	6.1	2	55	26.1	.....	....	......
94	"	Egyptian quarry ...	6.47	2.68	2.1	52.05	36.32	.....	....	......
95	Dade	Rising Fawn	...	.1		96.13	2.05	.95	....	.....
96	Floyd	Rome	10.95	3.5	2.05	43.8	8.79	....	....	......
97	Jefferson.......	Bartow... L	7.252	1.236		*a*34.07	*b*55.736	.....	....	1.622
98	"	"	1.94	1.5		56.02	38.43	.....	....	.....
99	Pickens	Dykes creek	.62	.25	....	97.34	1.6	....	....	.....

*a*CaCO *b*MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
65	FeO MnO } .46	U. S. geol. sur. Bul. 148, p. 272; W. F. Hillebrand, anal.	
66	FeO .09	U. S. geol. sur. Bul. 148, p. 272; G. Steiger, anal....	
67	FeO .23	" " " ...	
68	FeO .06	" " " ..	
69	FeO .61	" " " ...	
70	FeO .42	" " "	
71	FeO .19	" " " ,...	
72	FeO .22	" " "	
73	....	" p. 273, L. G. Eakins, anal..	Blue limestone
74	....	" " " ..	
75	....	" " " ..	
76	P_2O_5 .083	Am. inst. min. eng. Trans. 23:580...................	
77	FeO & MnO .21	U. S. geol. sur. Bul. 168, p. 274; W. F. Hillebrand, anal	
78	FeO & MnO .25	" "	
79	FeO & MnO 1.19	" "	Middle Carboniferous
80	FeO & MnO .32	" "	
81	FeO & MnO .20	" "	
82	FeO & MnO .32	" "	
83	FeO & MnO 3.08	" "	
84	FeO & MnO .1	" "	
85	FeO & MnO .17	" "	
86	FeO & MnO .07	" "	
87	FeO & MnO .15	" "	Triassic
88	....	U. S. geol. sur. 20th rep't, pt 6, p. 370; J. S. Adam, anal.	Canaan lime co
89	....	U. S. geol. sur. 20th rep't, pt 6, p. 370; J. S. Adam, anal.	" "
90	....	U. S. geol. sur. 20th rep't, pt 6, p. 370; J. S. Adam, anal.	Canfield Bros. quarry
91	....	Ga. geol. sur. 1893, p. 263; J. M. McCandless, anal.	
92	Org. .15	" p. 264; W. J. Land, anal........	
93	....	" " "	
94	....	" p. 266; J. M. McCandless, anal.	
95	....	" " "	
96	....	" p. 263 "	
97	....	U. S. geol. sur. 20th rep't, pt 6, p. 375; N. Pratt, anal.	A. C. Ladd lime works
98	....	U. S. geol. sur. 20th rep't, pt 6, p. 376; N. Pratt, anal.	" "
99	FeO .26	Min. res. U. S. 1890, p. 357; J. C. Jackson, anal.....	

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Georgia (*c'd*)									
100	Pickens	Dykes creek	6.25	1.7		52.64	39.44	....	.21	......
101	Polk...........	Cedartown	.....	....	2.23	94.37	2.1	......	....	......
102	"	Dewitte lime quarry	......	.4		95.2	2.171	.....	2.3	.....
103	"	Lookout creek.....	......	9.5	....	55.47	25.33	8.16	....	......
104	"	South of Trenton...	.....	1.8		91.4	3.5	2.82	....	......
105	"	Sand mountain	.....	3.2		80.6	2.45	1.27	....	......
	Illinois									
106	Adams	Marblehead	.47	2.18		95.62	.82	......	....	&org. .91
107	"	Quincy	......	.27		92.77	6.75	......	.37	......
108	Cook	Chicago	......	.55		52.75	44.28	.....	6	......
109	"	"	......	1.48		52.76	45.04	.....	.21	& loss .51
110	"	"	......	1.04		53.7	42.34	.....	1.28	.....
111	"	"	......	1.78		52.07	42.18	......	4	......
112	"	"	.....	.58		54.99	44.04	.....	.87	...
113	"	"	.34	2.04		23.39	19.4	......	54.15	......
114	"	"	.....	....	....	52.08	37.54	.....	....	.....
115	Kankakee	Kankakee...........	3	2.5		*a*30.45	*b*20.5	......	....	......
116	"	"	26.08	6.57		46.9	14.19	...	....	......
117	La Salle........	La Salle............	21.12	1.12		42.25	31.98	.....	....	1.07
118	Madison	Alton..............L.	1.01	1.1	......	*a*97.72	.....	......	....	......
119	Will	Joliet	3.70	2.5	......	92.14	1.75	......	....	......
	Indiana									
120	Adams	....	.53	.46	.01	54	45	....	....	.....
121	Blackford	Montpelier	2.75	4.7		*a*42.92	*b*3.88	41.2	....	.95
122	"	"	2.68	5.25		*a*42.55	*b*4.4	39.1	....	1.25
123	"	"	2.43	5.17		*a*43.01	*b*4.18	41.55	... .	1.—
124	Cass	Kenneth.............	1.33	2.07		98.48	*b*1.16	......	....	1.57
125	Clarke	Silver creek........	18.33	4.98	1.67	54.31	16.9	.....	....	......
126	"	"	9.69	2.77	1.95	51.95	32.97	.....	....	......
127	"	"	9.8	2.03	1.4	52.5	35.09	.....	....	......
128	Delaware.......	Muncie	......	3.72		51.96	38.11	....	3.3	......
129	Decatur	Greensburg	.....	55		94.6	.36	......	.87	.....
130	Elkhart	Mud lake	......	.41	.23	82 89	2 04	.....	7.94	.....
131	"	Cooley lake	.....	.52	.36	88.21	4.78	.....	1.42	......
132	Fulton	Manitou lake	......	.19	.3	87.65	2.6	......	6.39	.....
133	Franklin	Laurel	21 51	11.01		43 67	20.6	......	....	1.39
134	Harrison	Mauckport..........	......	.14	.18	98.09	....	......	.31	.12

a CaO   *b* MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS		REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
100	....		Ga. geol. sur. 1898, p. 265; J. M. McCandless, anal.	
101	Undet.	1.3	" p. 68; W. J. Land, anal.........	
102	....		" " "	
103	....		" " J. M. McCandless, anal.	
104	....		" p. 271; "	
105	....		" "	
106	....		U. S. geol. sur. 20th rep't, pt 6, p. 377: N. G. Bartlett, anal.	Marblehead lime co.
107	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; C. G. Hopkins, anal.	F.W. Menke stone and lime co.
108	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; T. C. Hopkins, anal.	Stearns stone and lime co.
109	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; J. B. Britson, anal.	Chicago Union lime works co.
110	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; T. C. Hopkins, anal.	Artesian stone and lime co.
111	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; T. C. Hopkins, anal.	"
112	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; T. C. Hopkins, anal.	Union lime co.
113	....		U. S. geol. sur. 20th rep't, pt 6, p. 377; T. C. Hopkins, anal.	Blue Island quarry
114	....		U. S. geol. sur. 20th rep't, pt 6 p. 377; T. C. Hopkins, anal.	Stony Island avenue quarry
115	P_2O_5	.006	U. S. geol. sur. 20th rep't, pt 6, p. 378; C. S. Robinson, anal.	Kankakee stone and lime co.
116	....		....	
117	....		Min. ind. 1:49..........	
118	FeO	.2	U. S. geol. sur. 20th rep't, pt 6, p. 378; S. E. Swartz, anal.	Armstrong quarry
119	....		Min. res. 1886, p. 542..........	
120	....		" 1890, p. 392	
121	SO_3 loss	.79 2.81	U. S. geol. sur. 20th rep't, pt 6, p. 382; S. S. Gorby, anal.	Baltes land co.
122	SO_3 loss	1.09 3.68	U. S. geol. sur. 20th rep't, pt 6, p. 382; S. S. Gorby, anal.	
123	SO_3 loss	.88 1.78	U. S. geol. sur. 20th rep't, pt 6, p. 382; S. S. Gorby, anal.	
124	loss	.39	U. S. geol. sur. 20th rep't, pt 6, p. 382; S. S. Gorby, anal.	Casparis stone co.
125	....		Ind. geol. sur. 1900, p. 366; W. A. Noyes, anal.....	"Ohio Valley" quarry
126	....		" " "	"Black Diamond" quarry
127	....		" " "	"Belknaps" Falls City quarry
128	....		U. S. geol. sur. Bul. 148, p. 263; C. Catlett, anal ..	Trenton limestone
129	....		" " " ..	"
130	Org.—	3.67	Ind. geol. sur. 1900, p. 331; Osborn eng. co., anal.	
131	Org.—	2.58	" " "	
132	Org.—	2.88	" " W. A. Noyes, anal....	
133	....		U. S geol. sur. 20th rep't, pt 6, p. 382; W. A. Noyes, anal.	J. A. Derbyshire
134	Alkalis	.40	U. S. geol. sur. 20th rep't, pt 6, p. 381; A. W. Smith, anal.	Mauckport quarry

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Indiana ((c'd)									
135	Harrison.......	Mauckport..........	.15	....	.64	93.8	4.01	......	.15	1.09
136	Howard........	Kokomo............	.24	.43	....	98.66	....	......	....	......
137	"	"	1.62	.6	.16	97.05	....	......	....	......
138	"	....	......	....	.001	93.1	....	......	1.62	......
139	"	....	......	....	.008	66.92	24.56	......	5.56	......
140	Huntington....	Huntington.........	2.75	4.7		*a*42.92	*b*4.41	41.2	....	.95
141	Jefferson.......	Big creek...........	......	....	.64	95.8	4.01	......	.15	1.09
142	"	"	......	....	.71	95.07	4.22	......	.5	1.19
143	Jennings......	Vernon............	....	.6		85.56	trace	......	8	......
144	Kosciusko	Syracuse lake.......	1.74	.9	.28	*a*49.84	*b*1.75	......	....	......
145	"	"	......	.9	.31	88.49	2.71	......	1.78	.....
146	"	Dewart lake........	......	.37	.16	92.35	3.54	......	2	......
147	"	"	......	.18	.3	84.24	2.85	......	4.52	......
148	"	Tippecanoe lake....	.....	.06	.26	90.67	2.42	......	2.48	......
149	"	" ...	......	....	.29	91.02	2.28	......	2.92	......
150	"	Little Eagle lake....	......	.15	.35	84.75	2.84	......	....	......
151	Lawrence......	Bedford.............	1.69	....	.49	97.26	*b*.37	....	....	.19
152	"	"	.89	.38	.25	*a*54.48	*b*.36	43.4	....	......
153	"	"	.87	.34	.13	*a*54.68	*b*.32	43.44	....	......
154	"	"	.64	.15		98.27	.84	......	....	......
155	"	"	63	....	.38	*a*54.19	*b*.39	44.01	....	......
156	"	"	1.69	....	.49	*a*54.18	*b*.37	43.08	....	......
157	"	"	......	1.27	.13	97.48	*b*.61	......	....	.15
158	Lagrange	Turkey lake.........	......	.61	.25	91.14	2.75	......	.85	......
159	Marshall	Maxinkuckee lake...	......	.12	.33	85.02	3.85	......	5.67	......
160	"	" ..	.....	.05	.33	85.38	3 5	......	6.4	......
161	"	" ..	53.2	26.76	4.24	12.66	3.03	.....	....	......
162	"	Houghton and Moore lake	....	.04	.2	89.22	2.73	.....	2.02	......
163	Miami.........	Peru	4.05	1.25	1.2	52.9	38.94	......	....	2.63
164	Monroe........	Bloomington........	......	.06	.23	95.62	.89	......	1.74	.59
165	"	"	......	.09	.09	95.55	.93	......	1.6	.42
166	"	"	......	....	1	95.54	.4	......	.65	.25
167	"	Stinesville..........	......	....	3	95	.22	......	.9	.05
168	"	Clear creek........	.84	.13		97.39	.78	......	....	......
169	Owen	4 m. e. of Spencer.	.....	....	.91	96.79	.23	......	.7	.41
170	Owen..........	Romona...........	1.26	.18		*a*54.82	*b*.31	43.49	....	......

*a*CaO

THE UNITED STATES (*continued*)

No.	MISCELLANEOUS		REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
135	....		U. S. geol. sur. 20th rep't, pt 6, p. 381; A. W. Smith, anal.	Big Creek quarry
136	MgO	trace	U. S. geol. sur. 20th rep't, pt 6, p. 382; Grasseli chem. co., anal.	Defenbaugh & Smith
137	MgO	.36	U. S. geol. sur. 20th rep't, pt 6, p. 382; Grasseli chem. co., anal.	"
138	....		Min. res. U S. 1890, p. 392..........................	
139	....		" "	
140	SO_3 Undet.	1.25 1.32	U. S. geol. sur. 20th rep't, pt 6, p. 382; G. M. Levette, anal.	Huntington white lime co.
141	....		Ind. geol. sur. 1900, p. 326; L. H. Streaker, anal...	Indiana steam stone works
142	....		" " " ...	"
143	....		U. S. geol. sur. Bul. 148, p. 263; C. Catlett, anal...	
144	SO_3 loss	1.12 46.01	Ind. geol. sur. 1900, p. 29; S. B. Newberry. anal..	Syracuse Portland cement co.
145	$CaSO_4$ Org.	1.58 4.23	" 321; " ..	
146	Org.	3.12	" " A. W. Burwell, anal..	
147	Org.	5.02	" " W. A. Noyes, anal....	
148	Org.	3.87	" " "	
149	....		" " "	
150	....		" " "	
151	....		U. S. geol. sur. 20th rep't, pt 6, p. 381; F. W. Clarke, anal.	Bedford quarries co.
152	....		U. S. geol. sur. 20th rep't, pt 6, p. 381; A. W. Smith, anal.	Bedford Portland cement co.
153	....		U. S. geol sur. 20th rep't, pt 6, p. 381; A. W. Smith, anal.	"
154	....		U. S. geol. sur. 20th rep't, pt 6, p. 381; A. W. Clarke, anal.	Bedford Indiana stone co.
155	P_2O_5	trace	U. S. geol. sur. Bul. 148, p. 263; F. W. Clarke, anal.	Hoosier stone co.
156	P_2O_5	trace	U. S. geol. sur. Bul. 148, p. 263; F. W. Clarke, anal.	" *see* no. 151
157	....		Ind. geol. sur. 1900, p. 328; A. W. Smith, anal	Bedford Portland cement co.
158	....		" 321; W. R. Oglesby, anal..	
159	$CaSO_4$ Org.	.17 3.21	" " W. A. Noyes, anal....	
160	$CaSO_4$ Org.	.17 3.15	" " " ..	
161	....		" 1885, p. 42..........................	
162	Org.	4.15	Ind. geol. sur. 1900, p. 321; W. A. Noyes, anal	
163	....		U. S. geol. sur. 20th rep't, pt 6, p. 382; J. N. Hurtz, anal.	Peru stone and lime co.
164	....		Ind. geol. sur. 1900, p. 326............................	Dunn & Dunn quarry
165	....		" "	"
166	Alkalis	.55	" "	Dunn & co.
167	Alkalis	.33	" "	Monroe marble co.
168	Alkalis	.1	U. S. geol. sur. 20th rep't, pt 6, p. 381	Acme Bedford stone co.
169	Alkalis	.32	Ind. geol. sur. 1900, p. 326	Simpson & Archer quarry
170	....		U. S. geol. sur. 20th rep't, pt 6, p. 382; W. A. Noyes, anal.	Romona oolitic stone co.

*b*MgO

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Indiana (*c'd*)									
171	Owen	Romona	1.26	.18		97.9	.65	......	....	......
172	Randolph	Union City	.....	1.23		83.21	12.48	......	2.14	......
173	Starke	North Judson	......	.45	.74	89.92	2.46	......	1.56	......
174	Steuben	Hog lake	......	.14	.28	90.42	2.88	......	.68	......
175	"	Lime lake	......	....	*c*1.16	86	9.42	......	1.08	.....
176	"	Deep and Shallow lakes	......	.04	.12	93.29	2.67	......	.47	......
177	"	James lake	......	....	.29	92.41	2.38	......	1.16	......
178	"	Silver lake	......	....	*c*1.34	84	6.46	......	4.52	......
179	St Joseph	Notre Dame lake	......	....	....	91.25	3.21	....	3.8	......
180	"	"	......	.05	.07	91.62	4.02	......	.19	......
181	"	Chain and Bass lakes	......	.1	.2	87.92	2.64	.....	3.1	......
182	"	Kankakee marsh	......	....	.08	91.3	2.9	......	.82	......
183	Wabash	Helms creek	34.2	18.76	*c*1.242	28	3.117	......	....	2
184	"	Lagro	35.6	17.86	*c*4.14	26	2.42	......	....	1.8
185	"	Wabash	......	7.58		53.18	30.53	......	3.52	......
186	"	Somerset	30.6	16.72	*c*2.48	25.6	12.713	......	....	1
187	Washington	Salem	.76	.15		98.16	.97	.....	....	......
188	"	"	.76	.15		*a*54.97	6	43.68	....	......
189	"	"	.63	....	.39	98.2	.39	.....	....	......
190	"	"	1.13	1.06		96.04	.72	......	....	.1
191	White	Rensselaer	.33	.14		56.28	43.26	......	....	......
192	Whitley & Noble	Loon lake	......	.41	.42	82.07	2.63	......	5.95	......
193	Wells	Bluffton	......	4.48		53.43	37.47	......	2.37	......
	Iowa									
194	Cedar	Near Rochester	.4	.1		78.75	20.16	....	....	...
195	Decatur	DeKalb	......	....	....	91.96	1.99	......	....	.07
196	Jackson	Monmouth	......	......	.53	57.54	41.51	......	.42	......
197	Marshall	LaGrande	......	.05		*a*55.05	*b*.28	43.62	.77	.13
198	"	"	......	.07		*a*54.85	*b*.28	43.3	.96	.21
199	"	"	.....	.18	.15	*a*50.56	*b*3.7	43.79	1.24	.15
200	"	"	......	.14	.15	*a*45.42	*b*8.21	44.85	.8	.19
201	"	"	......	.15	.31	*a*45.39	*b*8.28	44.76	.89	.12
202	"	"	......	.14	.26	*a*50.42	*b*3.96	43.85	1.22	.12
203	Plymouth	On Big Sioux river south of Westfield	......	....	....	83.7	2.48	......	....	.06
204	"	Deep creek n. e. of LeMars	....	....	....	94.39	.7	....	....	.06
205	Sioux	Hawarden	.75	6.68		64.3	5.38	.....	21.92	......
206	Allen	Humboldt	...	1.75		94.12	2.72	.....	1.53	......

a CaO *b* MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCES AND ANALYST	OWNER LOCATION AND REMARKS
171	....	U. S. geol. sur. 20th rep't, pt 6, p. 381; W. A. Noyes anal.	,Romona quarry. *see* no. 170
172	....	U. S. geol. sur. Bul. 148, p. 263; F. W. Clarke, anal.	Trenton limestone
173	Org. 4.51	Ind. geol. sur. 1900, p. 321; W. A. Noyes, anal......	Marl
174	Org. 4.13	" " "	"
175	Org. 2.32	" " C. R. Dryer, anal..	"
176	Org. 1.56	" " W. A. Noyes, anal......	"
177	CaSO₄ .15 Org 1.97	" " "	"
178	Org. 3.68	" " C. R. Dryer, anal........	"
179	Org. 1.5	" p. 25; H. H.Hooper, anal......	"
180	CaSO₄ .14 Org. 2.25	" p. 381; W. A. Noyes, anal......	"
181	CaSO₄ .23 Org. 4.18	" " "	"
182	CaSO₄ .22 Org. 3.88	" " "	"
183	loss 12.681	" 1891, p. 257...........................	Natural cement rock
184	loss 12.18	" 1891, p. 258...........................	"
185	....	U. S. geol. sur. Bul. 148, p. 263; C. Catlett, anal....	Trenton limestone
186	loss 10.687	Ind. geol. sur. 1891, p. 257.........................	Natural cement rock, Davis farm
187	....	U. S. geol. sur. 20th rep't, pt 6, p. 381; A. W. Smith, anal.	Twin Creek quarry
188	....	U. S. geol. sur. 20th rep't, pt 6, p. 382; W. A. Noyes, anal.	" *see* no. 187
189	....	U. S. geol. sur. 20th rep't, pt 6, p. 381; A. W. Smith, anal.	Hoosier quarry
190	Alkalis .15	U. S. geol. sur 20th rep't, pt 6, p. 381; A. W. Smith, anal.	Salem quarry
191	....	U. S. geol. sur. 20th rep't, pt 6, p 381; W. E. Stone, anal.	Ind. macadam & construction co.
192	CaSO₄ .22 Org. 6.71	Ind. geol. sur. 1900, p. 321; W. A. Noyes, anal....	Marl
193	....	U. S. geol. sur. Bul. 148, p. 263; C. Catlett, anal.....	Trenton limestone
194	MnO₂ .20	Iowa geol. sur. 11:336; N. Knight, anal	Lower Davenport limestone
195	....	" 8:308; J. B. Weems, anal.........	DeKalb limestone
196	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 383; S. Calvin, anal.	L. B. Stuart & Co.
197	FeO .09	Iowa geol. sur. 7:251; G. E. Patrick, anal.	Fine grained oolite, LaGrande quarry co.
198	FeO .27 MnO .08	" " " "	Blue limestone
199	FeO .09	" " " "	Iowa Caen stone
200	FeO .19	" " " "	Iowa marble, plain
201	FeO .1	" " " "	Iowa marble, colored
202	FeO .09 MnO trace	" " " "	Stratified limestone
203	....	" 8:359; J. B. Weems, anal...........	Chalk rock, old quarries
204	....	" " " "	"
205	....	" 10:152	Benton limestone
206	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	

c Ferrous carbonate.

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Kansas									
207	Allen	Humboldt	......	5.91		91.02	.14	.....	2.75	......
208	''	''	......	1.76		94.1	1.54	.....	2.63	......
209	''	''	....	1.21		95.2	1.1	.....	1.99	......
210	''	''	.....	1.07		93.2	1.01	....	3.79	......
211	Anderson	Garnett	.....	.81		92.76	.95	....	4.3	.43
212	''	''	....	and FeO 1.51	.....	97.32	.32	.....	.61	......
213	Barber	....	......	1.95		94.62	1.4	....	1.85	......
214	Brown	Horton	.....	5.53		81.91	1.56	....	11.83	......
215	Butler	Eldorado	......	.96		93.32	1.06	....	5.04	......
216	Chase	Strong City	.....	1.05		90	1.6	.....	7.3	......
217	''	Cottonwood Falls	....	3.62		84.72	1.75	.....	8.57	......
218	Cherokee	Galena	......	.69		97.32	.8	......	8	......
219	''	Short Creek	....	.17	......	[a]55.25	[b].35	43.79	.32	......
220	Clay	Clay Center	......	6.4		60.04	24.72	......	9.57	......
221	Cowley	Silverdale	5.27	1.07	.71	[a]50.36	[b].56	40.34	....	.78
222	''	Arkansas City	......	2.55		76.16	7.63	......	13.6	......
223	''	Winfield	......	.85		94.06	.62	......	4.25	......
224	''	Cambridge	......	1.69		93.98	.94	....	3.34	......
225	Douglas	Lawrence	......	1.07		94.18	1.16	......	3.53	......
226	''	''	......	1.79		95.02	.79	......	2.29	......
227	''	''	......	2.05		88.54	1.29	......	8.02	......
228	Elk	Moline	.....	2.13		93.49	3.04	......	.66	.....
229	Franklin	Greeley	......	3.09		92.71	2.64	......	1.18	......
230	''	Lane	......	2.38		94.77	1.07	......	1.18	......
231	''	''	......	& FeO .77	......	94.21	1.3	......	3.82	......
232	''	''	......	1.2		93.61	1.2	......	3.94	......
233	''	''	......	1.18		93.3	1.26	......	4.79	......
234	Hamilton	Coolidge	......	3.07		90.63	.84	......	4.81	.08
235	Hodgeman	Jetmore	......	2.08		91.3	.87	......	5.06	.44
236	Jackson	....	......	2.02		83.99	2.66	......	10.93	......
237	Jefferson	Winchester	......	1.04		90.01	1.66	......	6.98	......
238	Johnson	Ottawa	......	1.35		90	.12	......	8	......
239	Leavenworth	Lansing	.....	2.47		89.88	1.11	......	5.91	......
240	''	''	......	3.31		88.17	1.88	......	6.2	.04
241	''	''	.....	3.06		78.46	1.16	......	12.97	......
242	''	Soldier's Home	......	4.09		69.07	3.06	......	17.49	......

[a] CaO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
207	....	U. S. geol. sur. 16th rep't, pt 4, p 505; Williston. anal.	Iola marble co.
208	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
209	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
210	Sulfates .2	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
211	" .23	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	Carboniferous limestone
212	" .43	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	"
213	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
214	Sulfates .05	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	Frey Bros. quarry
215	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	Permian limestone
216	Sulfates .03	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	Carboniferous limestone
217	" .9	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	Bittiger Bros. quarry
218	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	Subcarboniferous limestone
219	FeO .2 MnO .02	U. S. geol. sur. Bul. 168, p. 263; L. G. Eakins, anal.	Cherokee limestone
220	....	" 16th rep't, pt 4, p. 504	Permian
221	Alkalis .3 P_2O_5 .06 FeO .32 SO_3 .07	" Bul. 168, p. 263; C. Catlett, anal...	
222	....	" 16th rep't, pt 4, p. 504; Williston, anal.	Permian
223	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	"
224	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	H. Heddeman quarry
225	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	Carboniferous
226	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
227	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
228	Sulfates .36	U. S. geol. sur. 16th rep't, pt 4. p. 505; Williston, anal.	
229	....	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	
230	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	Hanway quarry
231	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	"
232	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	"
233	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	"
234	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	Benton Cretaceous
235	....	U. S. geol. sur. 16th rep't, pt 4. p. 505; Williston, anal.	
236	Sulfates .14	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	A. W. Charles quarry
237	....	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
238	Sulfates .02	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	
239	Sulfates .88	U. S. geol. sur. 16th rep't, pt 4. p. 504; Williston, anal.	
240	Sulfates .28	U. S. geol. sur. 16th rep't pt, 4, p. 504; Williston, anal.	
241	Sulfates 2.32	U. S. geol. sur. 16th rep't, pt 4. p. 504; Williston anal.	
242	Sulfates .87	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	

*b*MgO

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Kansas (*cont'd*)									
243	Marion	Marion	......	3.15		53.16	38.33	......	5.13	......
244	"	"	......	1.91		59.21	30.09	......	6.85	.9
245	"	"	......	1.65		61.64	22.72	......	13.51	......
246	"	"	......	1.59		51.05	40.51	......	6.75	......
247	"	"	......	1.24		91.5	1.62	......	5.51	......
248	Marshall	Beattie	......	4.29		80.1	1	...	13.89	......
249	"	"	......	2.37		84.8	2.8	......	8.75	.25
250	"	"	......	1.34		80.31	3.87	......	14.01	......
251	Micami	Fontana	......	.95		96.5	.74	......	1.5	......
252	"	"	......	1.32		96.09	1	......	1.35	......
253	"	"	......	.82		95.57	.8	......	2.44	......
254	Montgomery	Independence	......	1.91		79.25	1.8	......	16.15	......
255	Nemaha	Sabetha	......	3.59		11.97	1.2	......	11.97	.29
256	Norton	Norton	......	& FeO .9		89	2	......	8.29	......
257	Trego	Wakeeney	14.06		5.1	[a]43.05	[b].5	35.08	....	1.77
258	Wabaunsee	Alma	......	1.74		89.68	1.99	......	6.22	......
259	"	"	......	.7		88.55	1.25	......	9.12	......
260	"	"	......	2.49		84.53	2.35	......	10.37	......
261	"	McFarland	......	2.61		92.5	1.62	......	3.27	......
262	Woodson	Yates Center	......	2.6		88.03	2.04	...	6.8	......
	Kentucky									
263	Anderson	Lawrenceburg	......	& MnO_2 2.03		85.2	1.24	......	10.425	......
264	Barren	Glasgow Junction	......	& MnO_2 .511		98.05	.363	......	1.06	......
265	"	"	......	& MnO_2 2.68		77.55	13.314	......	6.06	......
266	"	"	......	& MnO_2 2.68		82.96	7.655	......	6.16	......
267	Bath	W. side Clear creek	......	& MnO_2 9.02		53.26	18.531	......	17.54	......
268	"	Near Owingsville	......	& MnO_2 11.408		51.58	28.779	......	1.98	......
269	Bourbon	Quarry below woody pasture on William Buckner's land	......	& MnO_2 .542		96.51	1.049	......	1.886	......
270	"	Cane ridge, William Buckner's farm	......	& MnO_2 4.66		75.98	15.595	......	2.64	......
271	"	5 m. e. of Paris	......	.38	5.51	71.14	11.826	......	2.27	......
272	Bullitt	Bellemot furnace	......	& MnO_2 4.34		63.13	27.76	......	1.63	......

[a] CaO [b] MgO

THE UNITED STATES (*continued*)

No.	MISCELLANEOUS		REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
243	....		U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	Permian
244	Sulfates	.95	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	Carboniferous
245	....		U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal	I. Kuhn & Co. Permian
246	....		U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	" "
247	....		U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	Permian
248	Sulfates	.39	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	
249	Sulfates	.78	U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal	
250	....		U. S. geol. sur. 16th rep't, pt 4, p 504; Williston, anal.	Carboniferous
251	....		U. S. geol. sur. 16th rep't, pt 4, p 505; Williston, anal.	
252	....		U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
253	....		U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
254	....		U. S. geol. sur. 16th rep't, pt 4, p 505; Williston, anal.	
255	Sulfates	.55	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	
256	... .		U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston, anal.	Loup Fork Tertiary
257	....		U. S. geol. sur. bul. 168, p. 263; F. W. Clarke, anal.	Supposed marl
258	....		U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	
259	....		U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	A. Zechser quarry, Carboniferous
260	....		U. S. geol. sur. 16th rep't, pt 4, p. 504; Williston, anal.	
261	....		U. S. geol. sur. 16th rep't, pt 4. p. 505; Williston, anal.	
262	Sulfates	.21	U. S. geol. sur. 16th rep't, pt 4, p. 505; Williston. anal.	
263	P_2O_5 SO_3 Alkalis	.185 .17 .79	Ky. geol. sur chem rep't A, pt 2, p. 123	Lower Hudson River group
264	P_2O_5 SO_3 Alkalis	.051 .26 442	" " p. 119	Upper Subcarboniferous
265	P_2O_5 SO_3 Alkalis	.051 .192 342	" " p. 120	"
266	P_2O_5 SO_3 Alkalis	.115 .26 .291	" " "	"
267	P_2O_5 SO_3 Alkalis	.117 .633 .656	" " "	Lower Subcarboniferous
268	P_2O_5 SO_3 Fe_2CO_3 Alkalis	592 .235 3.095 .209	" " p. 122	Upper Silurian, Clinton group
269	P_2O_5 SO_3 Alkalis	.138 .18 .249	" " p. 123	Lower Hudson group
270	P_2O_5 SO_3 Alkalis	822 427 .207	" " p. 124	Trenton group
271	P_2O_5 Loss SO_3	.511 .64 .24	" " "	"
272	P_2O_5 SO_3 Alkalis	19 3.77 .59	" p. 121	Black Slate limestone

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Kentucky (*c'd*)									
273	Bullitt	H. C. Pindar's farm	.....	& MnO_2 2.17		51.93	17.662	......	6.183	......
274	Butler	Barren river, mouth of Gasper creek	.....	& MnO_2 .917		93.02	2.088	......	2.76	......
275	Caldwell........	4 m. e. of Princeton	......	....	....	97.64	1.18	......	1.16	......
276	Carter	Mt Savage furnace.	.....	& MnO_2 6.403		75.75	.575	....	14.7	......
277	"	Iron Hills furnace ..	......	& MnO_2 1.39		95.15	.245	......	3.06	......
278	"	Willard..............	......	.98		96.38	1.135	......	,38	......
279	Clark	Quarry, mouth of lower Howard's creek	......	& MnO_2 3.28		85.56	3.567	......	5.92	......
280	"	Stewart's mill, Lulbegrud creek	......	....	....	21.38	3.055	......	27.58	......
281	"	Howard's creek.....	.....	....	....	33.98	11.185	......	31.72	......
282	Crittenden	Crittenden furnace.	.....	& MnO_2 1.46		52.88	25.858	.....	18.88	......
283	"	"	.....	& MnO_2 1.323		55.28	29.246	......	14.28	......
284	Estill	5 m. from Irvine on Richmond turnpike	......	& MnO_2 3.546		41.38	30.019	....	18.68	......
285	Fayette.........	Dan'l Brink's quarry	......	& MnO_2 3.98		91.48	1.044	.....	2.38	......
286	"	Van Akin's quarry below Lexington	......	& MnO_2 2.42		92.73	.63	......	2.18	......
287	"	Van Akin's quarry below Lexington	.....	& MnO_2 3.23		77.63	10	......	4.98	......
288	"	Grimes's quarry, nr. Grimes's mill	....	& MnO_2 1.75		54.366	35.82	....	5.917	......
289	"	Harris's quarry, on Elk creek, 1 mile below Clays ferry.	....	& MnO_2 1.38		59.88	37.05	......	2.68	......
290	"	Raven creek, Daniel Brink's quarry	....	& MnO_2 3.67		70.07	19.252	.....	4.13	......
291	"	Dan'l Brink's quarry	......	& MnO_2 .38		95.68	2.044	......	1.58	......
292	"	Kentucky river bluffs	......	....	....	......	......	.....	....	......
293	"	Newton turnpike, 6 m. from Lexington	......	....	....	......	......	.....	....	......
294	"	Newton turnpike, at first tollgate	......	....	....	......	......	.....	....	......
295	Fleming.......	Hillsborough........	......	& MnO_2 12.434		42.68	25.358	......	10.88	......
296	Franklin........	Kentucky river bluffs	14.02	5.458	1.342	70.36	6.784	......	....	......
297	"	Near Bridgeport....	......	& MnO_2 1.19		92.65	1.54	...	3.68	......
298	"	" ...	......	& MnO_2 .769		95.38	1.51	......	2.08	......
299	"	Near Bright's mills..	......	& MnO_2 .124		89.625	.88	......	6.94	......
300	"	Big Benson creek ...	......	3.812		87.78	2.482	....	1.78	1.178
301	"	R. R. cut, 2 m. above Frankfort	.....	....	....	......	......	......	....	......

*a*CaO *b*MgO

THE UNITED STATES (*continued*)

No.	Miscellaneous	Reference and Analyst	Owner Location and Remarks
273	Alkalis .578	Ky. geol. sur. chem. rep't A, pt 2, p. 121..........	Upper Silurian, Niagara
274	P_2O_5 .243 SO_3 .604	" " p. 120..........	Upper Subcarboniferous
275	$FeO \& P_2O_5$ .28	" " p. 274..........	
276	P_2O_5 .057 SO_3 .775	" " p. 119..........	Coal Measures limestone
277	P_2O_5 .13	" " p. 120..........	Upper Subcarboniferous
278	$MnCO_3$ .953	" " p. 182..........	
279	P_2O_5 .118 SO_3 .474 Alkalis .884	" " p. 123..........	Trenton group
280	P_2O_5 9.71 Alkalis 1.058	" " p. 279..........	Oriskany group
281	P_2O_5 1.842	" " "	"
282	P_2O_5 1 SO_3 .003 Alkalis .649	" " p. 120.......	Lower Subcarboniferous
283	Alkalis .4	" " "	"
284	SO_3 1.471 P_2O_5 8.74 Alkalis .501	" " p. 121	Upper Silurian, Niagara
285	P_2O_5 .848 SO_3 .317 Alkalis .568	" " p. 123..........	Trenton group
286	P_2O_5 .86 SO_3 .34 Alkalis .51	" " p. 124	"
287	P_2O_5 .7 SO_3 8.12 Alkalis .47	" " "	"
288	P_2O_5 .31 SO_3 .23 Alkalis 1.57	" " "	"
289	Alkalis 1.03	" " "	"
290	P_2O_5 .246 SO_3 .303 Alkalis .45	" " "	"
291	P_2O_5 .182 SO_3 .166 Alkalis .241	" " p. 125..........	Birdseye limestone
292	P_2O_5 11.65	" " p. 259..........	Phosphatic
293	P_2O_5 3.88	" " p. 375..........	" Trenton
294	P_2O_5 3.487	" " "	"
295	P_2O_5 .843 Alkalis .823 Fe_2O_3 5.155 SO_3 .324	" " p. 122..........	Clinton limestone
296	Alkalis 1.899	" " p. 93.........	Trenton group
297	P_2O_5 .09 SO_3 1.27 Alkalis .43	" " p. 123.........	Lower Hudson River group
298	P_2O_5 .311 SO_3 .579 Alkalis .141	" " p. 124.........	Trenton group
299	P_2O_5 .44 SO_3 .680 Alkalis .58	" " "	"
300	P_2O_5 2.968	" " p. 259..........	Phosphatic; Lower Trenton
301	P_2O_5 4.029	" " p. 315.........	" Trenton group

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Kentucky (*c'd*)									
302	Garrard........	Burdett's Knob	......	& MnO_2 5.2		34.78	21.47	......	35.18	......
303	Grayson........	Falls of Rough creek	......	& MnO_2 2.56		85.68	2.503	.....	7.48	......
304	Greenup........	Pea ridge............	.....	& MnO_2 3.76		88.41	.797	....	5.96	......
305	"	Buffalo cr., Boome furnace	.....	& MnO_2 4.167		60.75	25.656	.....	5.68	......
306	"	Head of Old Town creek	......	& MnO_2 .152		88.15	.285	.....	9.56	......
307	"	Kenton furnace.....	......	& MnO_2 1.49		92.05	.22	......	4.46	......
308	Hardin	Sinking creek	......	& MnO_2 .88		79.18	11.469	....	6.98	......
309	"	Mr Moreman, 1½ m. s. of Big Spring	......	& MnO_2 .46		98.58	.629	......	.38	......
310	Harlan.........	½ m. from Creech postoffice	1.38	4.8		59	1.82	....	16.36	......
311	Henderson	Mount Zion	......	& MnO_2 1.76		88.38	3.678	....	3.28	......
312[1]	Indiana[1]........	Madison quarries[1]..	......	5.76		45.88	22.911	......	21.52	......
313	Jefferson.......	Louisville	......		2.93	50.43	18.67	......	25.78	......
314	"	Farm of Theodore Brown	......	& MnO_2 1.48		89.06	6.783	.....	2.68	......
315	"	Farm of Theodore Brown	......	& MnO_2 .48		92.56	4.615	......	2.58	......
316	"	Farm of Theodore Brown	......	& MnO_2 .726		87.78	7.096	.....	3.48	......
317	Lewis...........	Vanceburg..........	1.15	2.49		48.79	37.482	....	8.85	.547
318	Lyon.	Near Eddyville	.... .	.68		85.58	2.088	......	9.58	1.643
319	Madison........	Muddy creek, nr. J. R. Compton	......	& P_2O_5 10.33		48.53	11.79	......	20.74	&loss 6.567
320	"	Mill dam, Muddy creek, Elliston	20.98	17.656	3.7	37.76	10.05	..	25.18	&loss 4.902
321	"	Muddy creek	22.8	21.256	4.12	33.56	6.855	......	29.08	&loss 4.302
322	"	Below mill dam, Muddy creek	......	& P_2O_5 11.36	3.5	45.7	27.475	......	9.98	&loss 1.396
323	"	Below mill dam, Muddy creek	......	& P_2O_5 9.96	3.9	50.86	20.1	......	3.98	&loss 10.87
324	"	Below mill dam, Muddy creek	......	& P_2O_5 5.96	3.56	50.96	27.972	......	4.12	&loss 6.493
325	"	Below mill dam, Muddy creek	......	12.36	4.46	51.2	25.124	......	3.92	&loss 2.46
326	"	Quarry north of Rogersville	......	10.706	2.06	35.16	4.646	......	39.78	&loss 4.275
327	"	Near Elliston........	......	& P_2O_5 9.42	2.64	43.06	9.994	......	22.68	&loss 11.287
328	"	"	......	& P_2O_5 9.04	1.89	41.15	13.908	......	20.99	Etc. 13.022
329	"	1 m. s. of S. J. Embry's	......	& P_2O_5 10.98		47.58	17.133	......	18.19	&loss 6.117
330	"	Crittenden furnace.	......	& MnO_2 9.46		40.28	15.903	.....	23.18	......
331	"	Elliston, Covington's farm	......	& MnO_2 2.96		49.32	30.729	......	14.18	......
332	"	....	.....	4.01 & P_2O_5 1.54		36.58	18.541	......	....	......

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[1] Misplaced. Should be Madison. Jefferson co. Indiana.

THE UNITED STATES (*continued*)

No.	MISCELLANEOUS		REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
302	P_2O_5 SO_3 Alkalis	.31 .956 .601	Ky. geol. sur. chem. rep't A, pt 2, p. 121...........	Upper Silurian
303	P_2O_5 SO_3 Alkalis	.182 .839 .359	" " p. 120...........	" Subcarboniferous Coralline
304	P_2O_5 SO_3 Alkalis	1.78 .044 .509	" " p. 119...........	Coal Measures limestones
305	Fe_2CO_3 P_2O_5 SO_3	3.42 .013 .315	" " "	"
306	P_2O_5	.051	" " p. 120..........	Upper Subcarboniferous
307	P_2O_5 SO_3	.124 .199	" " "	"
308	P_2O_5 SO_3 Alkalis	156 .338 .271	" " "	"
309	P_2O_5 SO_3 Alkalis	.125 .274 .176	" " "	"
310	Org.	16.64	" " p. 283...........	Carboniferous limestone
311	P_2O_5 SO_3 Alkalis	.246 .166 .357	" " p. 119...........	Coal Measures limestone
312	P_2O_5 Alkalis	.22 .719	" " p. 93....	
313	Alkalis	..45	" " "	
314	P_2O_5 SO_3 Alkalis	.31 .475 .317	" " p. 121..........	Upper Silurian
315	SO_3 Alkalis	.166 236	" " "	"
316	P_2O_5 SO_3 Alkalis	.386 .358 .281	" " p. 122...........	Clinton group. Layer next to top
317	P_2O_5 Alkalis	.143 .548	" " p. 289.	
318	Alkalis	.429	" " p. 291..........	
319	....		" " p. 57..........	Clinton shaly limestone
320	P_2O_5	.204	" " "	"
321	....		" " "	Impure limestone
322	....		" " "	" on Cumberland shale
323	....		" " "	Niagara. Top stratum
324	FeS_2	.576	" " "	Second stratum from top
325	P_2O_5	.14	" " "	Niagara. Third stratum from top
326	P_2O_5	.754	" " "	Clinton limestone
327	....		" " "	From below Cauda-galli grit
328	....		" " "	Bituminous limestone above Corniferous
329	....		" " "	
330	SO_3 Alkalis	1.025 .6	" " p. 121...........	Black Slate limestone
331	Alkalis	.43	" " "	"
332	....		" " "	Corniferous

*a*CaO *b*MgO L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Kentucky (*c'd*)									
338	Mason..........	Near boundary with Fleming co.	......	& MnO_2 3.751		75.44	4.783	......	14.44	......
334	"	Mason co. tobacco land	......	& MnO_2 2.2		87.98	1.721	......	6.38	.....
335	"	Near boundary with Fleming co.	.....	& MnO_2 3.91		77.36	2.307	......	13.98	......
336	Mercer	Near Cornishville...	......	& MnO_2 2.34		88.9	1.468	......	7.185	.....
337	"	Farm of James C. McAfee	.....	& MnO_2 2.7		90.72	4.615	......	1 88	.....
338	"	No. 1 } No nearer location given	......	& MnO_2 1.22		62.86	30.72	.....	5	.....
339	"	No. 2 }	.....	& MnO_2 .98		83.58	10.55	......	5.56	.....
340	"	Kentucky river bluffs	......	1.22		62.86	30.72	......	5	
341	"	Kentucky river bluffs	......	10.55		83.04	10.55	......	5.56	2.3
342	Montgomery....	L. C. Jeffries farm, Aaron run	......	....		......	......	....	....	......
343	Muhlenberg ...	Arsdie furnace	......	& MnO_2 4.333		82.88	4.196	......	4.26	.....
344	Nelson	Nelson's furnace ...	......	& MnO_2 5.55		51.66	32	......	9.78	......
345	"	Troutman's	....	& MnO_2 2.1		50.48	38.154	....	8.38	......
346	"	Rolling Fork	.....	& MnO_2 3		49.78	34.456	......	10.78	......
347	"	Bardstown	......	2.978		81.58	1.501	.....	11.12	......
348	"	"	......	4.317		61.24	8.915	.....	22.52	......
349	Nicholas	R. R. cut Carlisle..	.....	& MnO_2 2.48		78.68	1.566	.....	16.64	......
350	Ohio............	3 m. below Hartford	.....	& MnO_2 8.64		41.68	22.748	.....	24.06	......
351	Owen	Harmony.........	....	& MnO_2 3.58		92.92	.559	......	1.72	......
352	Shelby	5 m. s. e. Shelbyville	....	5.917		40.78	24.511	....	25.12	2.168
353	Spencer.........	Upper Hudson river beds	....	2.478		87.32	.787	......	1.68	5.527
354	Warren	....	76	.....	.22	*a*54.8	tr.	33	....	.38
355	Woodford......	Near Versailles	......	& MnO_2 1.04		96.24	.945	......	.78	......
356	"	"	......	& MnO_2 1.53		91 33	.56	......	5.18	.....
357	"	Hills at Shyrocks ferry	......	& MnO_2 .63		94.75	1.96	......	2.18	......
358	"	Shyrocks ferry......	......	& MnO_2 .98		59.86	36.64	.....	2.48	....
	Louisiana									
359	Bienville........	Rayborn's Salt Lick	.55	1.61		*a*54.09	*b*.06	44.12	....	.05
360	Winn............	5 m. w. of Winnfield	......	trace	......	*a*55.01	*b*.6	43.43	.65	.13

*a*CaO *b*MgO

THE UNITED STATES (*continued*)

No.	MISCELLANEOUS		REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
333	P_2O_5 SO_3 Alkalis	.409 .474 .332	Ky. geol. sur. chem. rep't A, pt 2, p. 123	Upper Hudson. Oxidized
334	P_2O_5 SO_3 Alkalis	.348 .372 .336	" " "	" "
335	P_2O_5 SO_3 Alkalis	.31 2.433 .492	" " "	" "
336	P_2O_5 SO_3 Alkalis	.631 .235 .221	" " "	Lower Hudson. Under subsoil of old field
337	Alkalis	.349	" " p. 124..........	Trenton
338	....		" " p. 125..........	Chazy limestones
339	....		" " "	"
340	....		" " p. 259.... ...	" *see* no. 338
341	....		" " "	" *see* no. 339
342	P_2O_5	.473	" " p. 315	Phosphatic limest. of Trenton
343	SO_3 P_2O_5 Alkalis	4.717 .247 .285	" " p. 119..........	Coal Measures limestone
344	SO_3 Alkalis	.09 1 23	" " p. 121..........	Black-slate limestone
345	P_2O_5 SO_3 Alkalis	.118 .289 .518	" " p. 122....	Upper Silurian
346	P_2O_5 SO_3 Alkalis	.246 .475 .276	" " "	" "
347	P_2O_5 Alkalis	1.202 .671	" " p. 222..........	Upper Hudson river
348	P_2O_5 Alkalis	.563 .697	" " "	"
349	P_2O_5 SO_3 Alkalis	.247 .27 .345	" " p. 123..........	Lower Hudson river
350	P_2O_5 Alkalis	.153 1.576	" " p. 119..........	Coal Measures limestone
351	P_2O_5 SO_3	.349 .338	" " p. 123..........	Lower Hudson river
352	P_2O_5 SO_3	.563 .941	" " p. 259....	Upper Silurian
353	P_2O_5 Alkalis	1.842 .866	" " "	
354	Alkalis	6.48	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 388	Caden stone co.
355	P_2O_5 SO_3 Alkalis	.63 .178 .87	Ky. geol. sur. chem. rep't A, pt 2, p. 123	Lower Hudson river
356	P_2O_5 SO_3 Alkalis	.7 .33 .77	" " p. 124...........	Trenton limestone
357	P_2O_5 SO_3 Alkalis	trace .3 .262	" " p. 125...........	Birdseye limestone
358	SO_3 Alkalis	.16 .48	" " "	Chazy limestone
359	SO_3	.05	U. S. geol. sur. Bull 168, p. 258; R. B. Riggs, anal..	
360	....		U. S. geol. sur. Bull 168, p. 258; W. F. Hillebrand, anal.	White marble, black streaks

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	A_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Maine									
361	Knox	Rockland	1.08	.07	......	a54.97	b.04	43.25	....	......
362	"	Union........	1	....		95.2	1	......	....	2.7
363	"	Warren.....	.95	....		53.52	45.13	......	....	.4
	Maryland									
364	Allegany.	Cumberland........	24.74	16.74	6.3	41.8	8.6	.....	....	......
365	Baltimore	Cockeysville...	.....	.4		a20.08	b20.3	44.26	5.57	......
366	Frederick	Walkersville	4.73	1.4		93.57	.34	.....	....	......
367	"	"	4.31	.9		81.97	13	......	....	.....
368	"	Frederick	.22	.29	.25	97.32	2.03	.....	....	......
369	"	"	.1	.16	trace	96.79	2.86	......	....	......
370	Washington....	Cavetown.....	.47	....		a55.51	....	.....	....	......
371	"	Specimens from different places in Hagerstown Valley	5.8	.1		a50.79	b1.57	41.58	....	......
372	"		.25	....		a56.18	b1.31	44.01	....	......
373	"		2.4	.6		a53.07	b1.07	42.87	.. ..	......
374	"		3	.27		a30.21	b20.37	46.06	....	......
375	"		.7	....		a30.76	b21.12	47.4	....	......
376	"		2	.64		a31.64	b14.69	41.03	....	......
377	"		.6	....		a55.18	b.41	43.81	....	......
378	"		6	.2		a50.79	b1.43	41 48	....	......
379	"		.2	.1		a54 32	b1.19	43.99	....	......
380	"		2	.3		a53.2	b1.24	43 16	....	......
	Massachusetts									
381	Berkshire......	Renfrew	.63	.55		99.6	.49	......	....	......
382	"	" L	.26	.15	......	a98.13	b.42	.6	....	.2
383	"	" L	.81	.47		a96.63	b.88	.12	....	......
384	"	Cheshire	.31	.23		98.8	.37	.35	....	......
385	"	New Lenox........L	1.14	.17		a95.66	b.76	......	....	......
386	"	West Stockbridge...	......	....		99.029	.266	.....	....	......
387	"	Lee	.95	.09	......	a54.75	b.56	43.38	....	.08
388	Franklin..	Charlemont..........	.67	trace	.08	a28.63	b16.17	45.35	....	......
389	Worcester ...	Webster.....	1.01	.17	.....	a30.82	b21.35	45.84	....	.09

aCaO bMgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
361	FeO .08	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 398; F. C. Robinson, anal.	J. H. McNamara quarry
362	FeO trace	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 398; F. C. Robinson, anal.	G. W. Bachelder
363	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 398; S. P. Sharpless, anal.	McLoon & Stover lime co.
364	....	Md. geol. sur. Allegany co. rep't, p. 186.	Salina group
365	....	U. S. geol. sur. Bul. 168, p. 253; E. A. Schneider, anal.	
366	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 401; H. J. Patterson, anal.	J. W. Stimmel, no. 1
367	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 401; H. J. Patterson, anal.	J. W. Stimmel, no. 2
368	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 401; J. O. Hargrove, anal.	M. J. Grove lime co. (dark stone)
369	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 401; J. O. Hargrove, anal.	M. J. Grove lime co. (light stone)
370	Loss on ign. 44.02	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 401; Lehman & Glaser, anal.	P. G. Zouck & Co.
371	Und. .12	Md. geol. sur. 1898, p. 197; Dr J. Higgins, anal.....	Limestones of Shenandoah formation
372	Und. .25	" " "	
373	....	" " "	
374	....	" " "	
375	....	" " "	
376	....	" " "	
377	....	" " "	
378	....	" " "	
379	Und. .3	" " "	
380	Und. .1	" " "	
381	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 410; E. E. Olcott, anal.	Adams marble co.
382	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 410; P. S. Burns, anal.	J. Follett & Sons
383	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 410, H. P. Eddy, anal.	J. Follett & Sons
384	Org. .85	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 410; Davenport & Williams, anal.	Cheshire mfg co.
385	Ign. 8	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 411; W. M Habirshaw, anal.	Hutchinson Bros.
386	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 411; J. B. Britton, anal.	C. H. Hastings
387	Alkalis .17 P_2O_5 .08 FeO .1	U. S. geol. sur. Bul. 168, p. 252; G. Steiger, anal..	Cut on west side of railroad
388	FeO 7.6	U. S. geol. sur. Bul. 168, p. 252; L. G. Eakins, anal.	
389	Alkalis .11 FeO .37 P_2O_5 .06	" " " H. N. Stokes, anal.	

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Michigan									
390	Alpena	Alpena	.....	trace		98.54	1.24	......	....	......
391	''	'' ...L	1.96	.94		*a*95.6	*b*.14	......	....	& CO_2 1.36
392	''	'' ...L	3.42	1.21		*a*94.26	*b*.32	......	....	& CO_2 .79
393	Charlevoix	Bayshore .L	1.09	1.74		*a*81.83	*b*13.42	......	....	& CO_2 1.92
394	''	'' ...L	.7	.66		*a*96.8	*b*.67	......	....	& CO_2 1.17
395	Emmet	Petoskey	......	......	......	87.65	11.22	......	....	......
396	Huron	Bayport	3.33	1.334		91.538	.944	......	....	......
397	Monroe	2 m. n. e. of Dundee	.48	......	.16	90.8	6.87	......	....	......
398	''	''	1.1	......	.12	86.8	11.6	......	....	......
399	''	''	2.78	......	.56	77.6	17.41	......	....	......
400	''	''	.81	......	.41	95	3.86	......	....	......
401	''	''	.7	......	......	98.1	.63	......	....	......
402	''	''	1.86	.62		86.96	10.08	......	....	......
403	''	Lulu	.....	......	......	54	42	......	4	......
404	''	2. m. n. of Monroe city	2	.7		54.54	42.75	......	....	......
405	''	2. m. n. of Monroe city	.74	.98		54.47	43.59	......	....	......
406	''	2. m. n. of Monroe city	1.33	.58		54.94	42.84	......	....	......
407	''	n. e ¼, s. w. ¼, sec. 8, Ash township	...	.48		55.03	42.17	......	2.32	......
408	Wayne	Trenton	.6	.06		98.53	.53	......	....	......
409	''	''	.4	.08		97.5	1.26	......	....	......
	Minnesota									
410	Dodge	Mantorville	......		1.77	50.2	38.96	......	6.33	......
411	Fillmore	Fountain	.....	1.3		86.107	.47	......	9.89	......
412	''	Lanesboro	......	.33	.37	49.66	42.06	......	3.45	......
413	''	''	......	1.05		62.14	28.49	......	7.35	......
414	Goodhue	Frontenac	......	.31	.36	54.78	42.53	......	2.93	......
415	''	Red Wing	....	.37	.55	50.68	33.61	......	....	......
416	Hennepin	Minneapolis	......	......	4.03	41.88	24.55	......	29.93	......
417	''	''	......	3.16	.9	54.533	36.002	.....	16.22	......
418	''	''	......	1.7		75.482	6.81	......	14.45	......
419	Lesueur	Kasota	......	1.09		49.16	37.53	......	13.06	......
420	''	''	....	......	1.49	47.904	35.227	.....	13.85	......
421	Ramsey	St Paul	......	2.67	1.63	79.18	6.42	......	13.39	......
422	Steele	Clinton Falls	......	1.94		57.08	15.9	......	25.51	......
423	Washington	Stillwater	......	.64	.78	50.22	37.39	.....	8.54	......
424	Winona	Winona	......	.96		51.23	41.33	......	6.32	

*a*CaO *b*MgO

THE UNITED STATES (*continued*)

No.	MISCELLANEOUS	REFERENCE AND ANALYST	LOCATION AND REMARKS
390	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 412......	R. Collins quarry
391	....	" " p. 413......	
392	....	" " "	
393	....	" " " ...... E. J. Schneider, anal.	Petoskey lime co.
394	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 413; E. J. Schneider, anal.	"
395	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 412; Strong & Dunham, anal.	H. O. Rose quarry
396	Org. & loss 2.854	Mich. geol. sur. 7, pt 2, p. 214........................	
397	Org. 1.69	" pt 1, p. 76; G. A. Kirschmeier, anal.	B. E. Bullock quarry
398	....	" " "	"
399	Org. 1.63	" " "	"
400	....	" " "	"
401	S .055	" " K. J. Sundstrom, anal.	"
402	S .123	" " "	"
403	....	" p. 87..........................	H. McCarthy quarry
404	....	" p. 95; K. J. Sundstrom, anal	Monroe stone co.
405	....	" " "	"
406	....	" " "	"
407	....	" p. 92 "	
408	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 412	Sibley quarry co.
409	....	" " "	"
410	....	G. P. Merrill, Stones, for bld'g and decoration, p. 467	Hooke's quarry
411	....	" " "	
412	....	" " "	Mill co. quarry
413	....	" " "	
414	....	" " "	
415	....	" " "	Sweeney's quarry
416	....	" " "	Foley & Herbert quarry
417	....	" " "	Weekes & Hoschers quarry
418	....	" " "	Eastmans quarry
419	....	" " "	
420	....	" " "	Breckenridge Bros. quarry
421	....	" " "	A. Raus's quarry
422	....	" " "	
423	....	" " "	Hersey & Co. quarry
424	....	" " "	

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Minnesota (c'd)									
425	Winona	Gunflint lake	2.7	.35	7.23	49.8	6 65	......	....	.47
426	....	Ogiskemannissi lake	41.99	1.24	.42	a16.85	b8.41	24.7	MnO .26	1.07
	Mississippi									
427	Chickasaw	Okolona	......	1.957	1.421	81.77	.877	.....	10.903	......
	Missouri									
428	Greene	Ash Grove.........L	.12	.054	.011	a99.815	trace	.....	....	......
429	"	"	......	.48	.4	92.75	3.26	.....	.495	.675
430	"	Springfield	.33	....	.21	99.46	......	.....	......	......
431	Jasper	Sarcoxie	.....	.88	.05	98.34	trace	.....	.42	......
432	"	Joplin	.....	1.32		a21.46	b14.79	33.13	29.77	......
433	Marion	Hannibal	.08	.4		98.8	.02	.....	....	......
434	Newton	Seneca	......	.11	......	a55.29	b.23	43.69	.66	......
435	"	"	......	.13	.....	a54.92	b.2	43.31	1.21	......
436	"	Grand Falls	.....	.08	......	a54.98	b.31	43.54	1.01	......
437	"	"	......	.13	.....	a55.11	b.32	43.65	1.01	......
438	Ralls	Hannibal	.....	....		99.64	.21	.....	.15	......
439	St Louis	Glencoe	......	.68		98.36	b 26	.....	.7	......
440	"	....	.....	......	.2	97.76	.12	.....	.26	......
	Montana									
441	Lewis & Clarke	Helena	1.45	.16	.76	88.25	5.7	.....	....	......
442	"	N. of East Gallatin river	......	.22		54.54	43.63	.....	.34	......
443	"	W. of North Boulder river	.....	.4		54.54	42.62	.....	1.78	......
444	"	N. of East Gallatin river	......	2 5		67.85	6.18	.....	23.5	......
445	"	N. of East Gallatin river	......	1.92		59.11	1.96	....	35.26	......
446	"	West side Bridger range	......	.38		88.5	.95	....	9.98	......
447	"	N. of Gallatin river	......	.58		91.96	1.35	.....	5 99	......
448	"	"	......	.3		32.28	13 91	.....	50.74	......
449	"	"	.....	5.3		40.21	25.25	.....	25.24	....
	Nevada									
450	Eureka	Eureka	.....	....		a30.6	b21.69	47.13	.53	......
451	"	"	24	.12	.12	a41.97	b.8	32.62	....	.16
452	"	"	3.94	.64	.43	a51.96	b.52	40.71	....	.37
453	"	"	9.34	.31	.29	a50.01	b.54	39.11	Org. tr.	.13
	New Jersey									
454	Hunterdon	Annandale	.....	.98		a28.27		38 88	16.9	......
455	"	Amsterdam	......	1.4		a46.6	....	36.6	14.1	......
456	"	Clinton	......	1.9		a27.7	b17.4	43	7.2	......

*a*CaO *b*MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
425	FeO 3.85 SO_3 .32	U. S. geol. sur. Bul. 148, p. 265	
426	FeO 4 77	" " " T. M. Chatard, anal.	
427	K_2O .248 Ign. 2.84 Na_2O .321	Ark. geol. sur. 1888, p. 237	"Rotten Limestone"
428		Min res. 1889-90, p. 407; C. W. Eoff, anal	
429	Alkalis 1.94	" " W. D. Church, anal	
430		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 415; R. Chauvenet & Bro. anal	Marble Head lime co.
431		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 415	"
432		" Bul. 168, p. 263; L. G. Eakins, anal.	
433		" 20th rep't, pt 6 cont'd, p. 415	Hannibal lime co.
434	MnO trace FeO .05	" Bul. 168, p. 263; L. G Eakins, anal.	Cherokee limestone
435	MnO trace FeO .07	" " " "	"
436	MnO .03 FeO .05	" " " "	"
437	MnO trace FeO "	" " " "	"
438		" 20th rep't, pt 6 cont'd, p. 415	Star lime co.
439		" " " "	Glencoe lime and cement co.
440		Min. res. 1889-90, p. 407	
441		U. S. geol. sur 20th rep't, pt 6 cont'd, p. 416	Persell limestone co.
442		" Bul. 168, p. 269; C. Catlett, anal	
443		" " " "	
444		" " " "	
445		" " " "	
446		" " " "	Base of Carboniferous
447		" " " "	Middle Carboniferous
448		" " " "	Upper Carboniferous
449		" " " "	"
450		" " p. 276; E. A. Schneider, anal.	
451	P_2O_5 .07	U. S. geol. sur. Bul. 168, p. 276; W. F. Hillebrand, anal.	Base of Hamburg limestone
452	FeO .2 MnO .61 P_2O_5 .5	U. S. geol. sur. Bul. 168, p. 276; W. F. Hillebrand, anal.	Summit "
453	P_2O_5 .24	U. S. geol. sur. Bul. 168, p. 276; W. F. Hillebrand, anal.	Pogonip limestone (Silurian)
454		N. J. geol. sur. 1900, p. 33	Gano's quarry
455		" 1868, p. 393	W. Vanderbilt farm
456		" " "	Light gray, S. H. Leigh quarry

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	N. Jersey (*c'd*)									
457	Hunterdon.....	Clinton..............	......	3.7		*a*26.4	*b*15.1	45	9.8	......
458	"	"	......	6.5		*a*27.3	*b*14.6	44.8	4.9	......
459	"	"	......	.84		*a*29.8	*b*19.93	......	7.23	......
460	"	Newton...............	.....	1.1		*a*28.61	*b*20.52	44.88	5.9	......
461	"	"	......	1.06		*a*29.62	*b*20.63	......	4.92	......
462	"	"	......	1.4		*a*30.13	*b*21.71	.....	1.95	......
463	"	New Germantown ..	......	6		*a*21.2	*b*13.2	31.3	25.8	& loss 2.5
464	"	Near Pattenburg....	8.42	2.3	......	*a*44.64	*b*.36	34.47	....	......
465	"	"	18.6	5.8	......	*a*38.76	*b*.66	31.2	....	......
466	"	Pennwell...........	.....	....		*a*29.87	......	.....	2	......
467	"	"	.....	....		*a*29.64	......	.....	2.8	......
468	"	"	......	....		*a*25.75	......	....	1.9	......
469	"	"	......	....		*a*26.65	......	.....	4.1	......
470	"	Vernoy..............	2.28	.545	1.34	52.45	43.25	......	....	......
471	"	Middletown[1]	......	.75		*a*49.1	*b*1.13	......	10.49	......
472	Morris..........	Mendham, 1 m. e....	.....	1.6		*a*33.95	*b*18.21	27.66	16.4	......
473	"	"	......	15.7		*a*23.74	*b*16.82	26.2	14.7	& loss 2.84
474	"	Montville...........	......	.8		*a*30.41	*b*19.29	42.6	4.8	.9
475	Passaic.........	Macopin.............	......	2.2		*a*29.5	*b*20.3	45.6	1.1	1
476	"	Middle Forge........	......	9.7		*a*27.3	*b*18.1	42	4	......
477	"	West Milford........	.....	1.8		*a*29.6	*b*20.3	45.5	2.7	......
478	Salem	Mannington township	23.31	.91	3.07	69.61	*b*1.81	.....	....	.24
479	"	Swede's Bridge	8.11	.86	3.56	84.73	*b*1.4	......	....	.45
480	Somerset.......	Pepack	......	4	1.3	*a*26.3	*b*17.4	41.1	8	.7
481	"	"	......	1.6		*a*30.3	*b*18.3	44.1	4.1	.. ...
482	"	"	......	3		*a*31.6	*b*18.3	45.2	1.6	... .
483	"	Pottersville	.....	8.4		*a*32.4	*b*15.5	42.5	2	......
484	Sussex	Andover	......	.45		*a*55.13	......	43.32	.85	.....
485	"	"	......	.7		*a*52.41	trace	41.19	5.7	......
486	"	"	......	.6		*a*52.41	trace	41.19	5.5	......
487	"	"	......	5.9		*a*49	*b*2.88	38.5	.9	1.8
488	"	Beaver Run.........	......	.38	......	*a*54	*b*1	......	2.62	......
489	"	"	......	1.48	......	*a*46.66	*b*.31	.....	14.27	......
490	"	"	....	1.14		*a*53.64	*b*.81	42.72	2.54	......
491	"	e. of Beaver Run ..	......	1.03		*a*47.8	*b*1.35	......	13	......
492	"	Branchville	.....	.6		*a*48.6	*b*4.2	43.9	2.6	......
493	"	Carpenter's Point...	8.5	16.9		*a*39.87	*b*1.42	33.31	....	.6

Analyses 460, 461, 462 and 471 should have been placed under Sussex co.

THE UNITED STATES (*continued*)

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
457		N. J. geol. sur. 1868, p. 393	Average from Leigh's quarry
458		" " "	J. Mulligan & Bro. quarry
459		" 1900, p 33	"
460		" " "	O'Donnell & McManniman quarry
461		" " "	O'Donnell & McManniman quarry
462		" " "	O'Donnell & McManniman quarry
463		" 1868, p. 393	Calcareous conglomerate
464		" 1900, p. 50	Trenton limestone
465		" " "	"
466		" 1878, p. 105	J. Warner quarry. Blue magnesian limestone
467		" " "	J. Warner quarry. Blue magnesian limestone
468		" " "	J. Warner quarry. Blue magnesian limestone
469		" " "	J. Warner quarry. Blue magnesian limestone
470	Phos. .035	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 420; H. Weaver, anal.	E. Weise estate
471		N. J. geol. sur 1900, p. 58	Trenton limestone
472		" 1878, p. 104	Crystalline limestone. Saunders quarry
473		" 1868, p. 402	Serpentine limestone
474		" " p. 401	Turkey mountain, Boonton iron co.
475		" " p. 393	Average, R. Gould quarry
476		" " "	
477		" " p. 393	D. Cisco quarry
478		" " p. 441	Yellow limestone
479		" " "	Limesand. Pit of J. Fowler
480		" " p. 392	Drab stone. H Hilliard quarry
481		" " "	Best of M. Craig quarry
482		" " "	Average selected sample
483		" " "	
484		" " p. 403	White limestone, hill north of Andover, Boonton iron co.
485		" " "	White limestone, hill north of Andover. Boonton iron co.
486		" " "	White limestone, hill north of Andover, Boonton iron co.
487		" " p. 479	Shell marl, J. J. Decker's, 1 m. s. w. of Andover
488		" 1900, p. 70	Webster Kernick's farm
489		" " "	"
490		" " 71	J. B. Hardens
491		" " 70	F. Kemble's farm
492		" 1868, p. 398	Fossiliferous. ½ m. n. e. of Branchville
493		" " p. 399	Firestone Nearpass quarry

*a*CaO *b*MgO L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	N. Jersey (c'd)									
457	Hunterdon.....	Clinton..............	......	3.7		*a*26.4	*b*15.1	45	9.8	......
458	"	"	......	6.5		*a*27.3	*b*14.6	44.8	4.9	......
459	"	"	......	.84		*a*29.8	*b*19.93	......	7.23	......
460	"	Newton.............	.....	1.1		*a*28.61	*b*20.52	44.88	5.9	......
461	"	"	......	1.06		*a*29.62	*b*20.63	......	4.92	......
462	"	"	......	1.4		*a*30.13	*b*21.71	.....	1.95	......
463	"	New Germantown ..	......	6		*a*21.2	*b*13.2	31.3	25.8	& loss 2.5
464	"	Near Pattenburg....	8.42	2.3	......	*a*44.64	*b*.36	34.47	....	......
465	"	"	18.6	5.8	......	*a*38.76	*b*.66	31.2	....	......
466	"	Pennwell..........	.....	....	....	*a*29.87	......	.....	2	......
467	"	"	.....	....	....	*a*29.64	......	.....	2.8	......
468	"	"	.....	....	....	*a*25.75	......	....	1.9	......
469	"	"	.....	....	....	*a*26.65	......	.....	4.1	......
470	"	Vernoy.............	2.28	.545	1.34	52.45	43.25	......	....	......
471	"	Middletown[1]	......	.75		*a*49.1	*b*1.13	......	10.49	......
472	Morris..........	Mendham, 1 m. e....	.....	1.6		*a*33.95	*b*18.21	27.66	16.4	......
473	"	"	......	15.7		*a*23.74	*b*16.82	26.2	14.7	& loss 2.84
474	"	Montville...........	......	.8		*a*30.41	*b*19.29	42.6	4.8	.9
475	Passaic.........	Macopin............	......	2.2		*a*29.5	*b*20.3	45.6	1.1	1
476	"	Middle Forge.......	......	9.7		*a*27.3	*b*18.1	42	4	......
477	"	West Milford.......	.....	1.8		*a*29.6	*b*20.3	45.5	2.7	......
478	Salem	Mannington township	23.31	.91	3.07	69.61	*b*1.81	.....	....	.24
479	"	Swede's Bridge	8.11	.86	3.56	84.73	*b*1.4	......	....	.45
480	Somerset.......	Pepack	......	4	1.3	*a*26.3	*b*17.4	41.1	8	.7
481	"	"	......	1.6		*a*30.3	*b*18.3	44.1	4.1	.....
482	"	"	......	3		*a*31.6	*b*18.3	45.2	1.6	....
483	"	Pottersville	.....	8.4		*a*32.4	*b*15.5	42.5	2	......
484	Sussex	Andover	......	.45		*a*55.13	......	43.32	.85	.....
485	"	"	......	.7		*a*52.41	trace	41.19	5.7	......
486	"	"	......	.6		*a*52.41	trace	41.19	5.5	......
487	"	"	......	5.9		*a*49	*b*2.88	38.5	.9	1.8
488	"	Beaver Run.........	......	.38	......	*a*54	*b*1	......	2.62	......
489	"	"	......	1.48	......	*a*46.66	*b*.31	.....	14 27	......
490	"	"	....	1.14		*a*53.64	*b*.81	42.72	2.54	......
491	"	e. of Beaver Run ..	......	1.03		*a*47.8	*b*1.35	......	13	......
492	"	Branchville	.....	.6		*a*48.6	*b*4.2	43.9	2.6	......
493	"	Carpenter's Point...	8.5	16.9		*a*39.87	*b*1.42	33.31	....	.6

Analyses 460, 461, 462 and 471 should have been placed under Sussex co.

THE UNITED STATES (*continued*)

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
457		N. J. geol. sur. 1868, p. 393	Average from Leigh's quarry
458		" " "	J. Mulligan & Bro. quarry
459		" 1900, p 38	"
460		" " "	O'Donnell & McManniman quarry
461		" " "	O'Donnell & McManniman quarry
462		" " "	O'Donnell & McManniman quarry
463		" 1868, p. 393	Calcareous conglomerate
464		" 1900, p. 50	Trenton limestone
465		" " "	"
466		" 1878, p. 105	J. Warner quarry. Blue magnesian limestone
467		" " "	J. Warner quarry. Blue magnesian limestone
468		" " "	J. Warner quarry. Blue magnesian limestone
469		" " "	J. Warner quarry. Blue magnesian limestone
470	Phos. .035	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 420; H. Weaver, anal.	E. Weise estate
471		N. J. geol. sur 1900, p. 58	Trenton limestone
472		" 1878, p. 104	Crystalline limestone. Saunders quarry
473		" 1868, p. 402	Serpentine limestone
474		" " p. 401	Turkey mountain, Boonton iron co.
475		" " p. 393	Average, R. Gould quarry
476		" " "	
477		" " p. 393	D. Cisco quarry
478		" " p. 441	Yellow limestone
479		" " "	Limesand. Pit of J. Fowler
480		" " p. 392	Drab stone. H. Hilliard quarry
481		" " "	Best of M. Craig quarry
482		" " "	Average selected sample
483		" " "	
484		" " p. 403	White limestone, hill north of Andover, Boonton iron co.
485		" " "	White limestone, hill north of Andover, Boonton iron co.
486		" " "	White limestone, hill north of Andover, Boonton iron co.
487		" " p. 479	Shell marl, J. J. Decker's, 1 m. s. w. of Andover
488		" 1900, p. 70	Webster Kernick's farm
489		" " "	"
490		" " 71	J. B. Hardens
491		" " 70	F. Kemble's farm
492		" 1868, p. 398	Fossiliferous. ¼ m. n. e. of Branchville
493		" " p. 399	Firestone Nearpass quarry

*a*CaO *b*MgO L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	N. Jersey (*c'd*)									
494	Sussex	Carpenter's Point...	4	1.1		*a*52.52	*b*.33	41.8	....	.....
495	"	" ...	22 8	8.94	2.57	*a*20.44	*b*12.03	31.06	....	1.1
496	"	" ...	4.1	.9		*a*52.92	.....	41.58	....	.....
497	"	" ...	...	1.1		*a*51.52	.....	40.5	5.3	.....
498	"	Centerville	.....	....		64.2	.....	.....	16.21	16.59
499	"	Chandler's island ..		1.1	.6	*a*27.6		41.9	9.9	.2
500	"	Dingmans Ferry....	[illegible]	[illegible]		*a*50.79	*b*.44	40.37	....	.8
501	"	Drake's pond, near Newton	....	[illegible]		*a*52.85	*b*.76	.....	3.19	.....
502	"	Franklin	.....	.5		*a*53.53	*b*1.73	43.97	.55	.....
503	"	Hamburg...........	15.7	6		42.28	33.26	1.35	....	.....
504	"	Hardystonville	.....	.15		*a*51.8	*b*1.37	42.23	1.7	1.8
505	"	Hamburg	7.02	5 43		47.4	37.19	*c*1.17	....	.....
506	"	Hunts Mill.........	.....	....		96.32	1.57	....	1.16	.96
507	"	Iliff's pond	.....	1.82		*a*54.04	*b*.81	.....	2.87	.....
508	"	"	9.5	1.42		*a*47.95	*b*.57	.....	3.55	.....
509	"	Jenny Jump mountain	.....	1		*a*42.45	*b*10.23	44.67	1.91	.....
510	"	Lafayette	....	1.81		*a*49.11	*b*.65	....	9.53	.....
511	"	N. W. of Lafayette.	...	.61		*a*39.12	*b*8.21	.....	13.52	.....
512	"	N. of Lafayette.....	10.72	1.46		*a*49.13	*b*.34	....	2.69	.....
513	"	N. J. bank, Milford ferry	....	1.8		*a*47.34	*b*1.24	38.9	10.3	.....
514	"	Monroe Corners	.....	....		94.75	.....	.....	.71	4.54
515	"	"	...	1.49		*a*49.03	*b*.7	.....	10.67	.....
516	"	3 m. s. w of Monroe	.....	1.63		*a*43.09	*b*.73	....	26.51	.....
517	"	Montague	8.7	1.5		*a*49.67	*b*.69	40	....	.....
518	"	"	.43	.45		*a*50.27	*b*.62	38.57	....	&org. 6.07
519	"	"	.37	.16		*a*50.38	*b*.36	38.9	....	&org. 4.83
520	"	"	1.21	2.12	1.28	*a*9.71	*b*.42	7.25	66.57	&org. 7.6
521	"	"	1.15	2.49		*a*8.45	*b*.43	6.12	66.97	&org. 10.46
522	"	Newton[1]...........	.....	.6		*a*29.4	*b*20.3	45.7	1.8	.....
523	"	"	.....	.9		*a*28.6	*b*18.1	34.5	9.3	.....
524	"	"	.....	.9		*a*29	*b*20.2	44.9	4.8	.....
525	"	"	.....	4 7		*a*49	*b*.9	39.4	5.8	.....
526	"	"	.....	....		96.54	1 47	....	2.05	.....
527	"	"	.....	....		84.52	1.76	.....	8.46	&org. 5.26
528	"	"	.....	1.9		*a*28.22	*b*19.07	.....	8.13	.....
529	"	3 m. s. w. of Newton.	.....	1.6		*a*46.88	*b* .4	.....	11.96	.....
530	"	4 m. n. e. "	.....	2.44		*a*41.12	*b* 3.78	.....	17.58	.....

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[1] See also analyses 460, 461, 463 and 471.

THE UNITED STATES (*continued*)

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
494	....	N. J. geol. sur. 1868, p. 399	Blue limestone. Nearpass quarry
495	K_2O 1.34 P_2O_5 .25	" " "	Cement layer. Nearpass quarry
496	....	" " "	Quarry stone. Nearpass quarry
497	....	" " "	Best stone. Nearpass quarry
498	....	" 1877, p. 24	F. Layton's farm
499	Alkalis .5	" 1868, p. 395	
500	....	" " p. 460	Travertine
501	....	" 1900, p. 78	J. Ayres' farm
502	....	" 1871, p. 41	White crystalline limestone
503	....	" 1873, p. 108	Quarry of R. Howell
504	....	" 1868. p. 404	G. W. Rude. White limestone
505	....	" 18 3 p. 108	R. Howell's farm
506	....	" 1877, p. 24	D. M. Howell. Marl
507	....	" 1900, p. 79	Trenton limestone
508	....	" " "	"
509	....	" 1868, p. 402	White limestone. East side of mountain
510	....	" 1900, p. 74	Z. Simmons' farm
511	....	" " p. 75	Trenton limestone
512	....	" " p. 74	J. C. Demorest
513	....	" 1868, p. 399	Corniferous
514	....	" 1877, p. 24	Marl. White Pond
515	....	" 1900, p. 73	Trenton limestone
516	....	" " "	"
517	....	" 1868, p. 399	Lower Helderberg. J. Cole's farm
518	....	" " p. 479	Surface. I. Bonnell farm, Chamber's Mill brook
519	....	" " "	Same 10 ft below surface
520	....	" " "	Dark gray marl. 8 ft below surface. J. Cole
521	....	" " "	Marl. I. Van Etten, 4 ft below surface
522	....	" " p. 395	Moore & Cutler quarry
523	....	" " "	"
524	....	" " "	"
525	....	" " p. 398	W. T. Babbitt's farm
526	....	" 1877, p. 24	M. Drake's farm. Marl
527	....	" " "	
528	....	" 1900, p. 33	O'Donnell & McManniman quarry
529	....	" " p. 80	Whittingham estate
530	....	" " p. 76	

*a*CaO *b*MgO L = Analysis burned lime

ANALYSES OF LIMESTONFS OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	N. Jersey (*c'd*)									
531	Sussex..........	4 m. n. e. of Newton.	......	1.04		*a*37.95	*b*11.68	......	8.48	...
532	"	"	......	2.37		*a*30.46	*b* 9.82	......	24.91	.....
533	"	Myrtle Grove........	......	1.09		*a*48.36	*b* .56	......	11.86	....
534	"	Huntsburg..........	......	1.94		*a*50.16	*b* 1.67	.....	5.5	......
535	"	"		1.41		*a*47.55	*b* .65	....	14.85	......
536	"	Ogdensburg..........	.5	3.5		*a*29.68	*b*20.07	45.51	....	......
537	"	Peters valley	9.8	2.1		*a*48.88	*b* .35	38.9	....	......
538	"	"	.38	.8		*a*43.68	*b* .14	34.44	19.39	.36
539	"	Roseville............	......	......	1.5	*a*53.31	*b* 1.7	43.78	....	......
540	"	Sparta	9.5	1.2		*a*28.31	*b*18.04	42.08	....	.....
541	"	"	......	1.7		*a*28.5	*b*17.3	41.5	9.9	.3
542	"	"	......	.8		*a*51.06	*b* 3.02	43.44	1.4	......
543	"	Springdale..........	......	.8		*a*49.4	*b* 1	40.1	6.6	......
544	"	"	......	.81		*a*54.26	*b* 1.09	....	1.7	......
545	"	"	......	1.19		*a*50.65	*b* .55	40.41	7.83	......
546	"	Stillwater...........	......	.2		*a*54.7	.....	43	1.8	......
547	"	"	......	1.6		*a*43.2	*b* 2.2	31.4	15.8	......
548	"	Swartswood.........	......	4.37		*a*24.89	*b* 3.74	......	43.38	......
549	"	Sussex lead mine ...	.....	1		*a*51.07	*b* 3.02	47.47	.3	......
550	"	Vernon township ...	......	.5	.3	*a*30.4	*b*19.1	44.9	3.6	.3
551	"	Cranberry reservoir.	......	.7		*a*53.93	*b* 1.25	43.76	1	......
552	"	Vernon township ...	......	.9		*a*4.84	*b* 5.25	43.8	.27	.2
553	"	" ...	......	.9		*a*54.79	....	43.06	.75	.15
554	"	Walpack Center	......	2.1		*a*44.85	*b* 2.18	37.68	12.8	......
555	"	" Ridge......	......	2.6		*a*45.19	*b* .8	36.75	10.8	......
556	"	Wantage township..	......	2.2	.5	*a*30	*b*19.4	44.9	2.3	.5
557	"	" ..	......	1.3	.9	*a*29.3	*b*19.5	44.6	4	.3
558	"	" ..	......	.7	.5	*a*29.1	*b*19.3	43.4	6.4	3
559	"	" ..	......	.3	.6	*a*27.9	*b*17.7	41.4	11.2	.3
560	"	" ..	......	.4	.2	*a*30.3	*b*16.2	41.6	9.8	.7
561	"	West Vernon.... ..	......	.2		*a*51.96	*b* 2.92	44.03	.2	......
562	"	Wynokie	......	5.3		*a*29.01	*b*10.8	23	29.3	2
563	Warren	Asbury	.....	.8		*a*29.4	*b*17.8	42.8	8.8	......
564	"	B lvidere	1.86	.6	.51	*a*53.64	*b* .81	43.08	....	......
565	"	"	2.52	.44	.47	*a*53.24	*b* 1.08	42.62	....	......
566	"	"	2.03	.57	.51	*a*53.02	*b* .91	42.69	....	......
567	"	"	5.03	2.06	1.53	*a*49.73	*b* 1.02	40.19	....	......

*a*CaO *b*MgO

THE UNITED STATES (*continued*)

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
531		N. J. geol. sur. 1900, p. 76	Trenton limestone
532		" " "	
533		" " p. 55	¾ mile s. w. Myrtle Grove
534		" " p. 81	North of Huntsburg schoolhouse
535		" " "	North of Huntsburg schoolhouse
536		Geol. of N. J. 1868, p. 404	Tunnel n. e. of Sterling Hill
537		" " p. 399	J. Schooley farm
538		" " p. 479	Tufa. B. P. Van Syckle farm
539		" " p. 402	O. Himenover farm
540		" " p. 403	Crystalline limestone, J. B. Titman farm
541		" " p. 394	Blue limestone, J. B. Titman farm
542		N. J. geol. sur. 1871, p. 44	Crystalline limestone, J. B. Titman farm
543		Geol. of N. J. 1868, p. 398	D. Farrell farm
544		N. J. geol. sur. 1900, p. 82	J. Wolf farm
545		" " p. 83	J. Farrell farm
546	Alkalis .4	Geol. of N. J. 1868, p. 393	W. A. Mains quarry
547		" " "	A. T. Mains quarry
548		N. J. geol. sur. 1900, p. 56	⅛ mile west of railroad
549		Geol. of N. J. 1868, p. 403	Crystalline limestone
550	Alkalis 1.5 P_2O_5 .2	" " p. 395	¼ mile n. w. of W. Richey house
551		" " p. 402	Musconetcong iron co. quarry
552	Alkalis .5	" " p. 404	P. J. Brown quarry
553	Alkalis .16	" " "	"
554		" " p. 398	R. Stoll farm
555		" " p. 399	C. Decker farm
556	Alkalis .1	" " p. 395	300 yds. from D. Perry house
557	" .3	" " "	¼ mile n. w. of S. Vanderhoof
558	" .3	" " "	300 yd. west of W. Dewitt
559	" .3	" " "	Near house of E. Lewis
560	" .2	" " "	"
561		N. J. geol. sur. 1871, p. 44	Crystalline limestone
562	Alkalis .21	Geol. of N. J. 1868, p. 401	"
563		" " p. 394	M. Fox quarry, *see* p. 933
564		N. J. geol. sur. 1900, p. 95	Series of analyses made from samples taken chiefly on Morris & Earye farms near Belvidere. Analyses are all of the Trenton beds, which in this area furnish Portland cement rock
565		" " "	
566		" " "	
567		" " "	

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	N. Jersey (*c'd*)									
568	Warren........	Belvidere...........	5.37	3.45	.98	*a*49.5	*b*.85	39.84	....	......
569	"	"	5.76	3.25	1.36	*a*49.3	*b*.64	39.44	....	......
570	"	"	5	2.84	1.28	*a*48.72	*b*.96	39.33	....	......
571	"	"	8.38	4.03	1.32	*a*45.45	*b*1.34	37.18	....	......
572	"	"	11.9	4.42	1.7	*a*44.18	*b*1.18	36.01	....	......
573	"	"	11.71	4.[illegible]	1.62	*a*43.47	*b*1.82	36.15	....	......
574	"	"	12.46	4.82	1.62	*a*43.44	*b*1.15	35.41	....	......
575	"	"	12.8	5.39	1.7	*a*42.85	*b*1.35	35.16	....	......
576	"	"	11.11	4.4	1.91	*a*42.51	*b*2.89	36.57	....	......
577	"	"	13.82	5.03	1.7	*a*42.3	*b*1.49	34.86	....	......
578	"	"	14.54	5.59	1.83	*a*41.19	*b*1.46	34.08	....	......
579	"	"	20.59	5.33	1.87	*a*38.38	*b*1.39	31.67	....	......
580	"	"	14.9	7.42	1.87	*a*38.2	*b*1.09	31.2	....	......
581	"	"	17.04	6.9	2.13	*a*37.53	*b*2.17	32.88	....	......
582	"	"	22.71	5.84	2.13	*a*36.5	*b*1.69	30.52	....	......
583	"	"	22.39	6.9	1.74	*a*36.41	*b*1.53	30.3	....	......
584	"	"	16.2	6.71	1.91	*a*36.37	*b*3.21	32.1	....	......
585	"	"	19.53	6.03	1.7	*a*35.71	*b*3.33	32.73	....	......
586	"	"	22.77	6.58	2.52	*a*35.05	*b*1.52	29.2	....	......
587	"	"	22.96	7.35	2.04	*a*35.03	*b*1.59	29.28	....	......
588	"	"	24.45	5.68	1.57	*a*35	*b*2.21	29.89	....	......
589	"	"	27.9	7.89	1.7	*a*32.1	*b*1.4	26.78	....	......
590	"	"	22.72	8.15		*a*35.78	*b*1.86	...	....	......
591	"	"	......	1.4		*a*29.6	*b*19.2	46.2	2.9	......
592	"	"	......	1		*a*53.4	*b*.4	42.6	2.7	......
593	"	S. of Branchville....	......	.46		*a*54.98	*b*.84	......	2.27	......
594	"	Budgeville station..	27.08	8.76		55.37	3.83	......	....	2.6
595	"	Bushkill.............	......	1.3		*a*29.8	*b*19.3	44.7	4.3	......
596	"	Carpentersville	17.707	7.915		*a*41.794	*b*.38	33.25	....	......
597	"	"	14.595	6.861		*a*40.296	*b*.671	32.5	....	......
598	"	"	10.712	5.982		*a*39.999	*b*.654	32.15	....	......
599	"	"	10.262	7.186		*a*44.722	*b*1.401	36.68	....	......
600	"	"	20.578	5.441		*a*39.839	*b*.629	32	....	......
601	"	½ m. s. e. of Columbia	......	1.23		*a*52.58	*b*.65	.....	4.3	......
602	"	Columbia	......	1.4		*a*29.6	*b*20	45.4	2.3	......
603	"	Hainesburg	(2.62)	2.38		*a*48.04	*b*2.84	......	5.48	......
604	"	Hope................	......	....	....	89.87	2.29	......	.97	......

*a*CaO *b*MgO

THE UNITED STATES (*continued*)

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
568		N. J. geol. sur. 1900, p. 95	Series of analyses made from samples taken chiefly on Morris & Earye farms near Belvidere. Analyses are all of the Trenton beds, which in this area furnish Portland cement rock
569		" " "	
570		" " "	
571		" " "	
572		" " "	
573		" " "	
574		" " "	
575		" " "	
576		" " "	
577		" " "	
578		" " "	
579		" " "	
580		" " "	
581		" " "	
582		" " "	
583		" " "	
584		" " "	
585		" " "	
586		" " "	
587		" " "	
588		" " "	
589		" " "	
590		" " p. 94	Railroad cut
591		Geol. of N. J. 1868, p. 394	
592		" " p. 398	Fossiliferous limestone
593		N. J. geol. sur. 1900, p. 53	Trenton limestone
594	Undet. 2.86	" " p. 92	Iliff property
595		Geol. of N. J. 1868, p. 396	Wagner quarry, one mile from Easton
596		N. J. geol. sur. 1900, p. 42	Murphy farm
597		" " "	"
598		" " "	"
599		" " "	"
600		" " "	"
601		" " p. 66	Trenton limestone
602		Geol. of N. J. 1868, p. 395	First outcrop east of Van Kirk's tavern
603		N. J. geol. sur. 1900, p. 66	Trenton limestone
604	Org. and water 6.87	" 1877, p. 24	H. S. Cook. Marl

L = Analysis burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	N. Jersey (*c'd*)									
605	Warren	Jacksonburg	......	3.57		*a*2.41	*b*1.46	......	87.2	......
606	"	"	.....	.86		*a*55.7	*b*.45	......	.97	......
607	"	Lincoln	......	....	....	90.18	....	.....	9.75	......
608	"	Marksboro	......	....	....	92.25	2.98	......	1.56	......
609	"	New Hampton	....	1		*a*29.8	*b*19.9	45 4	3.4	......
610	"	Oxford	......	1.3		54.04	.53	43.06	.9	......
611	"	" Furnace	......	.33	.97	*a*50.3	42.4	......	5.5	......
612	"	Phillipsburg	......	1.1		*a*30.8	*b*19 2	45.4	3.6	......
613	"	Sarepta	......	1		*a*47.37	*b*2.06	.....	2.92	......
614	"	"	5.46	.81	1.02	*a*49.38	*b*2.26	......	....	......
615	"	Shiloh	....	....	....	97.73	....	......	.6	......
616	"	Springtown	.....	1.8	.6	29.2	18.8	43.6	3.6	.6
617	"	Stewartsville	23.04	8.15	2.41	*a*33.7	*b*.83	27.4	....	......
618	"	"	19.32	7	1.99	*a*36.86	*b*1.06	30.14	....	......
619	"	"	19.51	7.05	2.03	*a*36.8	*b*1.18	30.2	....	......
620	"	"	23.68	8.12	2.57	*a*33.3	*b*1.41	27.57	....	......
621	"	"	20.29	6.85	2.11	*a*36.84	*b*1.34	30.29	....	......
622	"	"	19.98	7.23	1.99	*a*36.78	*b*.58	29.54	....	......
623	"	"	21.1	7.68	1.92	*a*35.45	*b*.48	28.38	....	......
624	"	"	18.15	6.08	1.78	*a*38	*b*1.63	31.65	....	......
625	"	"	21.32	8.16	2.22	*a*35.19	undet.	27.56	....	......
626	"	"	21.72	8.27	2.34	*a*35.3	"	27.73	....	......
627	"	"	33.9	11.94		*a*27	"	21.21	....	......
628	"	"	35.95	11.28		*a*25.71	"	20.2	....	......
629	"	"	31.39	10.48		*a*38.84	"	22.66	....	......
630	"	"	17.97	8.27		*a*37.87	"	29.76	....	......
631	"	"	24.91	8.4		*a*34.44	"	27.02	....	......
632	"	"	35.07	11.6		*a*25 64	"	20.14	....	......
633	"	"	19.17	6.23	2.57	*a*37.51	"	29.47	....	......
634	"	"	20.2	5.92	2.53	*a*37.51	"	29.47	....	......
635	"	"	16.97	6.08	2.26	*a*38.29	"	30.09	....	......
636	"	"	19 87	7.83	3.95	*a*35.61	"	37.94	....	......
637	"	"	16.81	9.76		*a*38.81	"	.....	....	......
638	"	"	17.96	7.11	2.53	*a*37.95	"	29.82	....	......
639	"	Swayze's Mills	......	.82		*a*53.88	*a*.72	......	2.64	......
	New York									
640	Albany	South Bethlehem ...	9.05	6.66	.99	79.86	4.17	......	....	......

a CaO *b* MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
605		N. J. geol. sur. 1900, p. 63	Weathered sandy limestone
606		" " "	Pure limestone, same ledge as preceding
607		" 1877, p. 24.	Sink pond. Marl
608	Org.and water 3.21	" " "	White pond. Marl
609		Geol. of N. J. 1868, p. 394	J. Riddle quarry
610		" " p. 402	P. Raub quarry. White crystalline limestone
611		N. J. geol. sur. 1876, p. 55	Blue limestone
612		Geol. of N. J. 1868, p. 394	C. Twining's quarry
613		N. J. geol. sur. 1900, p. 94.	Trenton limestone
614		" " "	"
615	Org.and water 1.59	" 1877, p. 24	A. M. Cooke
616	Alkalis 8 P_2O_5 .2	Geol. of N. J. 1868, p. 394	R. Shimer quarry
617		N. J. geol. sur. 1900, p. 45	Trenton limestone from quarry of Edison Portland cement co., one mile n. e. of Stewartsville
618		" " "	
619		" " "	
620		" " "	
621		" " "	
622		" " "	
623		" " "	
624		" " "	
625		" " "	
626		" " "	
627		" " "	
628		" " "	
629		" " "	
630		" " "	
631		" " "	
632		" " "	
633		" " p. 46	
634		" " "	
635		" " "	
636		" " "	
637		" " "	
638		" " "	
639		" " p. 89	Trenton limestone
640		N. Y. state geol. rep't 1897, p. 430	Lower third of Callanan quarry

L = **Analysis burned lime**

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	New York (c'd)									
641	Albany........	South Bethlehem...	5.12	1 45	.74	*a*48.84	*b*2.93	41.22	....	......
642	“	“ ...	11.16	3.35	1.15	79.06	6.65	.....	....	......
643	Clinton.........	Chazy	.72	.39		96.24	3.02	......	....	......
644	“	“	.79	.14	.12	97 08	1 4	....	....	......
645	Columbia.......	Hudson............	1.84	.635	1.82	*a*51.4	*b*2.23	41.19	....	......
646	“	“	1.89	1.01	.55	91.7	3.51	......	....	......
647	Dutchess........	Clinton Point.......	10.17	[illegible]	.47	*a*29.07	*b*16.29	40.76	....	......
648	“	South Dover	.71	.37	.25	*a*30.63	*b*20 25	.....	....	......
649	Erie	Williamsville.......	.17	.84		98.54	1	.....	....	......
650	Essex...........	Willsboro Point.....	2.43	....		*a*51	*b*1	.....	....	......
651	Greene	Catskill............	2 75	1.5	1.6	*a*53.1	......	42.1	....	......
652	“	Sm ths Landing ...	1.54	.39	1.04	*a*53.87	*b*.52	.....	....	......
653	Herkimer.......	Little Falls..........	10.5	3.03	.77	47.96	36.89	..	....	......
654	“	Columbia..........	4.01	.48	.53	*a*51.82	*b*1.16	41 9	....	......
655	“	Ingham Mills.......	6.7	3.03	.21	89.15	trace	.....	....	......
656	“	“	8.45	2.72	.84	84.6	3.42	.....	....	......
657	Lewis..........	Port Leyden.........	6.5	1.67	.76	88.44	2.68	.....	....	......
658	“	Leyden..............	1.44	.83		97.36	1.04	....	....	......
659	“	Collinsville..........	3.09	1.15	.49	94.11	1.63	.....	....	......
660	“	Lowville............	3.96	1.7		91.27	3.78	.....	....	......
661	Monroe.........	Brighton	1.12	.27	.39	*a*29.38	*b*22.1	47.39	....	......
662	“	Gates	.7	.95	.8	*a*30.5	*b*20.05	45.24	....	......
663	“	Rochester..........	.29	.43	.46	56.01	43.3	....	....	......
664	Montgomery...	Amsterdam.........	1 25	3		*a*52.78	......	42.97	....	......
665	“ ...	“	3 82	1.08		*a*52.46	......	42.64	....	......
666	“ ...	“	5.68	2.76		*a*52,12	.....	39.44	....	......
667	“ ...	“	6.13	.79	.61	88.49	2.45	.....	.....	......
668	“ ...	“	7.46	2.48	1.07	71.76	18.19	.....	....	......
669	Niagara	Lockport...........	7.09	2.57	.96	56.19	33 42	......	....	......
670	“	Niagara Falls......	1.7	1.3	.75	*a*42.21	*b*17.45	37.5	....	......
671	Oneida.........	Prospect	2.59	1.21	.61	*a*52	*b*1.04	42	....	......
672	“	Near Clinton........	7.23	1.64		*a*48.68	*b*1.84	40.29	....	......
673	“	“	1.92	.36		*a*52.53	*b*.69	42.03	....	......
674	“	“	......	....		*a*35.25	*b*8.94	37.52	....	......
675	“	“	5.53	1.5		*a*50.25	*b*1	40.49	....	......
676	“	Oriskany Falls......	5.56	1.55		*a*50.47	*b*.83	40.57	....	......
677	“	“	2.57	1.55		*a*52.69	*b*.84	42 33	....	......

a CaO **b MgO**

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
641		N. Y. state geol. rep't 1897, p. 430	Middle third of Callanan quarry
642		" " p. 431	Upper third of Callanan quarry
643		" " p. 433; D. H. Newland, anal.	Chazy limestone
644		N. Y. state geol. rep't 1897, p. 433	
645		" " p. 431; T. Eggleston, anal.	Jones quarry
646		N. Y. state geol. rep't 1897, p. 431	"
647		" " "	
648	Alkalis .58	" " "	South Dover marble co. quarry
649	S 101	" " p. 436; H. Carlson, anal.	Fogelsonger & Young quarry
650		" " p. 437; J. F. Kemp, anal.	Partial analysis
651		" " " "	Holdredge's quarry
652		Engineering news. 45:365	Catskill cement co. quarry
653		N. Y. state geol. rep't 1897, p. 438	
654		" " "	Tentaculite limestone
655		" " p. 439	Birdseye, Butler quarry, lower massive layer
656		" " "	Birdseye, average of quarry
657		" " " D. H. Newland, anal.	Trenton limestone. P. Snyder farm
658		N. Y. state geol. rep't 1897, p. 440	Christy quarry
659		" " " D. H. Newland, anal.	Roberts quarry
660		N. Y. state geol. rep't 1897, p. 441	J. Waters quarry
661		" " "	Rochester lime co. quarry
662		" " p. 442; D. H. Newland, anal.	Snow quarry
663		N. Y. state geol. rep't 1897, p. 442; D. H. Newland, anal.	Copeland quarry
664		N. Y. state geol. rep't 1897, p. 443; Sherrerd, anal.	D. C. Hewitt quarry, upper layer
665		" " " "	D. C. Hewitt quarry, intermediate
666		" " " "	D. C. Hewitt quarry, lower
667		" " "	D. C. Hewitt quarry
668		" " p. 444	G. Ross quarry
669		" " p. 445; D. H. Newland, anal.	Quarry 2 miles e. of town
670		N. Y. state geol. rep't 1897, p. 445; H. Ries, anal.	W Messing quarry
671		" " " p. 446; J. D. Irving, anal.	Trenton limestone
672	S .21	N. Y. state geol. rep't 1897, p. 446; A. H. Chester, anal.	
673		N. Y. state geol. rep't 1897, p. 446; A. H. Chester, anal.	
674		N. Y. state geol. rep't 1897, p. 446; A. H. Chester anal.	
675	S .3	N. Y. state geol. rep't 1897, p. 446; A. H. Chester, anal.	
676	S .21	N. Y. state geol. rep't 1897, p. 446; A. H. Chester, anal.	
677	SO_3 .14	N. Y. state geol. rep't 1897, p. 446; A. H. Chester. anal.	

L = **Analysis burned lime**

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	New York (*c'd*)									
678	Oneida	Oriskany Falls	5.66	2.14		*a*50.25	*b*1.11	40.7	....	......
679	"	"	5.46	1.35		*a*50.8	*b*1.01	41.02	....	......
680	"	"	5.82	1.38		*a*50.93	*b*.85	40.87	....	......
681	Onondaga	Jamesville.........L	.....	2.03		*a*91.93	*b*3.06	.....	1.88	1.47
682	"	Manlius	20.3	13.67		*a*47.48	*b*18.55	.....	....	......
683	"	Jamesville.........L	10.97	4.46	1.54	*a*27.51	*b*16.9	37.94	....	......
684	"	"	10.95	5 32	1.3	*a*30.92	*b*13.64	38 31	....	......
685	"	Split Rock	5.35	.56	.61	85 41	18.86	......	....	......
686	Orange.........	Newburg	10.46	1.95	1.8	*a*27.75	*b*17.65	40.46	....	......
687	Rockland	Tomkins Cove	12	4.13	1.05	*a*26.34	*b*16.74	39.1	....	......
688	Rensselaer.	Hoosick Falls.......	1.2	2	1.5	*a*34.11	*b*8.97	.....	....	......
689	Saratoga..	Sandy Hill	......	.46	1.09	*a*29.05	*b*12.8	38.6	18.04	......
690	St Lawrence ...	Ogdensburg.........	4.42	2.23	.16	55.87	37.74	......	....	......
691	" ...	"	17.28	5.21	.92	58.17	18.46	......	....	......
692	" ...	Between Colton and Canton	.5	1.3		88.67	9.53	......	....	......
693	" ...	1 m. from Canton...	1.12	1.89		76.48	19.97	......	....	......
694	" ...	Gouverneur.........	1.85	.23	.38	92.29	4.28	......	....	......
695	Schoharie.......	Howe Cave..........	1.27	.73		97.24	1.39	......	....	......
696	"	Cobleskill.	4.31	.97		*a*51.05	*b*1.65	47.14	....	......
697	Ulster	Rondout	3.87	1.07	1.34	*a*54.11	*b* trace	40.6	....	
698	"	Wilbur	7.1	2.5	1.65	*a*45.22	*b* trace	39.1	....	......
699	Warren	Glens Falls..........	3 9	1.3	.....	*a*52.15	*b*1.58	...	....	......
700	"	"	1.1	.8	.5	*a*53.17	*b*.75	42.8	....	......
701	Washington	Smith's Basin.......	1.38	.58		*a*55.26	*b*.72	......	....	......
702	" L	"	......	.58		*a*95.5	*b* trace	......	1.06	&CO_2 2.08
703	"	"	.72	1.5		54.28	.8	43.1	....	......
704	Westchester,...	Annsville Cove	2.5	1.55		81.64	13.5	......	....	......
705	"	Ossining	87	.57	.25	*a*31.4	*b*19.95	......	....	......
706	"	"	5.12	.75		*a*25.42	*b*22.35	......	....	......
707	"	"	6.77	1.81		*a*45.02	*b*3 16	......	....	......
708	"	"	5 94	2.82		*a*29 05	*b*20.05	......	....	......
709	"	Pleasantville........	2.31	.4	.25	59.84	36.8		....	......
710	"	Tuckahoe	.24	.19	.21	*a*30.16	*b*21.25	47.3	....	.02
	Ohio									
711	Allen	Lima	......	....	....	*a*32.24	*b*17 36	43.92	1.64	......
712	Auglaize	St Mary's township.	......	3.12		52.18	38.42	....	3.18	......
713	"	"	......	2.48		56.94	35.55	......	1.66	......

a CaO *b* MgO

THE UNITED STATES *(continued)*

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
678	S .18	N Y. state geol. rep't 1897, p. 446 ; A. H. Chester, anal.	
679	S .12	N. Y. state geol. rep't 1897, p. 446	
680	S .07	" " "	
681	SO_3 .73	" " p. 449; Englehardt, anal.	E. B. Alvord & Co.
682			Brown cement co. Cement
683		N. Y. state geol. rep't 1897, p. 449	Upper cement layer. Alvord quarry
684		" " "	Lower cement layer. Alvord quarry
685		" " "	Solvay process co. quarry
686		" " p. 451 ; J. D. Irving, anal.	Miller quarry
687		N. Y. state geol. rep't 1897, p. 450	
688		" " p 452	McCaffery quarry
689		" " p. 453	Higley, Monty & Co. quarry
690		" " "	Upper stone, Howard quarry
691		" " p. 454	Lower stone, Howard quarry
692		" " " Prof. Priestly, anal.	
693		N Y. state geol. rep't 1897, p. 454 ; Prof. Priestly, anal.	Stevens quarry
694		N. Y. state geol. rep't 1897, p. 455; J. D. Irving, anal.	
695		Eng. News, 45, p. 365 ; C. A. Schaeffer, anal.	Helderberg cement co. quarry
696			Cobleskill quarry
697		N. Y. state geol. rep't 1897, p. 457	Newark lime & cement co quarry
698		" " "	B. Turner quarry
699	SO_3 .8	" " p. 459	Top-stone
700		" " p. 460	Lower stone
701		" " p. 461	Keenan lime co. quarry
702		" " "	
703		" " "	Keenan lime company
704		" " p. 466 ; J. D. Irving, anal.	2 miles west of Peekskill
705		N. Y. state geol. rep't 1897, p. 463	Sing Sing lime co. quarry
706		" " "	Mark's quarry
707	P_2O_5 .027	" " "	"
708		" " "	"
709		" " p. 466	Cornell quarry
710		" " p. 465	O'Connell & Hillery
711		U. S. geol. sur. Bul. 148, p. 261; F. W. Clarke and R. B. Riggs, anal.	Oil rock
712		U. S. geol. sur. Bul. 148, p. 262; C. Catlett, anal.	Gas rock, Pauck well
713		" " "	Bennett well

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Ohio (*cont'd*)									
714	Clark . ..	Cold Springs........	......	.23		54.05	44.94	.....	.49	......
715	"	New Carlisle.. ...	......	.29		96.8	2.07	......	.83	......
716	"	Springfield.........	......	.56		54.13	44.37	......	.65	......
717	"	"	......	.39		53.88	43.79	.....	1 55	......
718	Clermont	Point Pleasant	......	7		79.3	.91	......	12	......
719	Clinton	New Vienna	....		......	*a*47.16	*b*1.52	36.2	8 47	......
720	"	"	....		....	*a*49.04	*b*.58	37.64	9.93	
721	"	"	......		....	*a*51.18	*b*3.08	42.04	2.12	......
722	"	"	.....	....		*a*23	*b*12.9	30.82	28.43	.....
723	Columbiana ...	New Lisbon..... ..	9.01	3.38		85.55	2.82	....	... .	.....
724	"	"	12.63	5.04	2.43	75.51	3 86	......	....	.7
725	"	"	33.93	14.3	4.29	35 56	6 09	......	....	5.2
726	" ..	"	36.69	15.17	4.82	27.22	7.83	......	....	7.6
727	Darke	New Madison	....	3.6		64.91	17.98	......	11.11	......
728	"	"	......	....		51.7	45.26	.....	2.7	......
729	"	Greenville	......	....		44.69	50.11	....	4.6	......
730	Erie	Sandusky	......	.35		89.08	8.34	......	1.51	......
731	"	"	......	4.58		54.62	33.67	.....	3.65	......
732	Franklin	Columbus....	.....	.8		94.8	1.21	......	3.2	......
733	"	"	......	1.74		93.21	4.7	.....	....	.....
734	Fulton	Wauseon	......	7.28		42.82	28.11	.....	18.24	
735	Greene	Cedarville	......	.53		53.9	44.58	....	.88	......
736	"	Osborne	.....	.36		97.09	.82	......	1.64	.....
737	"	Yellow Springs	....	1.4		51.1	41.12	....	5.4	....
738	"	Xenia	.....	.18		86.54	2.99	......	9.23	......
739	Hancock	Arcadia	....	....		*a*47.17	*b*2.59	38.54	8 56	......
740	....	Findlay	1.55	.39		53.88	43.79	......	....	......
741	Hardin	Kenton	......	1.1		84.32	8.43	.....	5.26	.....
742	Highland	Greenfield	1	1.3		53.67	42.42	......	1.44	......
743	"	"	1.45	1		49.9	44.87	......	2.98	......
744	"	Lexington	1.6	2.2		54.1	41.77	......	....	......
745	"	Leesburg	.69	.9		49.76	45.77	.....	2.88	......
746	"	Napoleon	....	2.14		53.85	37.33	.....	2.66	......
747	Logan	Huntsville	......	3.15		57.23	33.16	.....	4.41	......
748	Lucas	Toledo	......	8.68		54.68	25.73	......	2.88	......
749	Madison ; ...	London	......	1.84		77.69	1.89	.....	15.9	......
750	Marion	Marion	......	2.3		86 22	9.27	......	2.86	......

*a*CaO *b*MgO

THE UNITED STATES (*continued*)

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
714	....	U. S. geol sur. 20th rep't, pt 6 cont'd, p. 432; E. Lovejoy, anal.	Casparis stone co.
715	....	Ohio geol. sur. Ec. geol 6:728; N. W. Lord, anal...	Brown quarries
716	....	" " 6:716 " ...	Pettigrew
717	....	" " 6:717 " ...	G. H. Frey quarry
718	....	Merrill. Stones for building and decoration. p. 46:	
719	....	U. S. geol. sur. Bul. 148, p. 260; F. W. Clarke and R. B. Riggs. anal.	
720	....	U. S. geol. sur. Bul. 148, p. 260; F. W. Clarke and R. B. Riggs, anal.	
721	....	U. S. geol. sur. Bul. 148, p. 260; F. W. Clarke and R. B. Riggs. anal.	
722	....	U. S. geol. sur. Bul. 148, p. 260; F. W. Clarke and R. B. Riggs, anal.	
723	....	Ohio geol. sur. 5:1109; N. W. Lord, anal...........	White limestone
724	....	" " "	First limestone below white, top stratum
725	....	" " "	First limestone below white, middle stratum
726	....	" " "	First limestone below white, lower stratum
727	....	U. S. geol. sur. Bul. 148, p. 261; F. W. Clarke, anal.	Trenton limestone
728	....	Ohio geol. sur. Ec. geol. 6:726; Wormley, anal.....	Northrop quarry
729	....	" " " "	Bierly quarry
730	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432.......	Olemacher lime co.
731	....	" Bul. 148, p. 262; C. Catlett, anal....	Trenton limestone
732	....	" 20th rep't, pt 6 cont'd, p. 432......	T. J. Price & Co.
733	....	" " " "	Casparis stone co.
734	....	" Bul. 148, p. 262; C. Catlett, anal....	
735	....	Ohio geol. sur. Ec. geol. 6:720; N. W. Lord, anal...	Ervin quarry
736	....	" " 6:728 " ...	G. Haddock quarry
737	....	Merrill. Stones for building and decoration, p. 468.	
738	....	U. S. geol. sur. Bul. 148, p. 261; F. W. Clarke, anal.	Trenton limestone
739	....	" " F. W. Clarke and R. B. Riggs, anal.	"
740	....	Ohio geol. sur. Ec. geol. 6:744; N. W. Lord, anal...	Barnd quarry
741	....	U. S. geol. sur. Bul. 148, p. 261; F. W. Clarke, anal.	McElree well
742	....	Ohio geol. sur. Ec. geol. 6:730; Wormley, anal.....	Rucker quarry
743	....	" " " "	Wright quarry
744	....	" " " "	"
745	....	" " " "	Pope quarry
746	....	U. S. geol. sur. Bul. 148, p. 262; C. Catlett, anal....	Trenton limestone
747	....	" " p. 261; F. W. Clarke, anal.	"
748	....	" " p. 262; C. Catlett, anal....	Air Line Junc.; depth 1415 ft
749	....	" " " " .. .	Depth 1594 ft
750	P_2 .11	" 20th rep't. pt 6 cont'd, p. 432.......	Norris & Christian lime & stone co.

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Ohio *(cont'd)*									
751	Marion	Prospect	.....	.		66.02	3.77	.....	26.12	.....
752	Mercer	Celina	.....	2.95		68.41	24.18	.....	2.95	.....
753	"	Fort Recovery	.....	1.57		87.88	7.43	.....	1.89	.....
754	"	Franklin township	.....	8.38		69.53	10.98	.....	3.68	.....
755	"	St Henry	.....	.....	.....	*a*50.34	*b*2.86	40.96	2.27	.....
756	Miami	Covington	3.77	.33	.67	53	37.11	.....	.....	.....
757	"	Rex	.....	.4		95.6	3.93	.....	.07	.....
758	Montgomery	Dayton	.....	.58		82.36	1.67	.....	12.34	.....
759	Ottawa	Genoa	.....	.16		54.3	45.14	.....	.23	.....
760	"	Port Clinton	.....	4.16		71.96	14.34	.....	7.46	.....
761	"	Genoa	.....	.23		55.97	44.27	.....	.04	.....
762	"	"	.....	.51		53.04	46.01	.....	.22	.....
763	"	"	.....	.16		54.3	45.14	.....	.23	.....
764	"	"	.....	.42		55.59	43.67	.....	.28	.....
765	"	"	.....	.44		54.61	45.05	.....	.24	.....
766	"	Rocky Ridge	.....	.29		54.1	44.27	.....	.87	.....
767	"	Williston	.21	.21		53.9	44.82	.....	.....	.....
768	Perry	Monday creek township	3.76	7.16		57.86	30.78	.....	.....	.1
769	Preble	New Paris	.....	.37		61.33	37.68	.....	.61	.....
770	Sandusky	6 m. w. of Fremont	.....	6.32		52.93	32.75	.....	5.22	.....
771	"	Woodworth	.....	.39		53.5	45.79	.....	.31	.....
772	Scioto	Elfort	.6	1.4		97.32	.45	.....	.....	.....
773	Seneca	Fostoria	.....	.28		56.41	41.98	.....	.42	.....
774	"	"	.....	2.7		52	45.26	.....	tr.	.....
775	"	Tiffin	.....	4.86		52.89	33.46	.....	5.66	.....
776	"	"	.....	1.46		79.39	6,2	.....	9.88	.....
777	"	"	1.61	.1	.07	*a*57.44	*b*40.36	.....	.....	.41
778	Williams	Bryan	.....	1.51		49	38.59	.....	9.22	.....
779	Wood	Bowling Green	.....	.4		53.88	44.91	.....	.3	.....
780	"	Luckey	.45	.36		54.1	44.9	.....	.....	.....
781	"	Sugar Ridge	.....	.69		55.23	43.12	.....	.84	.....
782	"	Toledo	4.95	.02	.....	57.3	36.7	.....	.....	.21
783	"	"	.....	.....	.....	*a*30.64	*b*18.05	42.82	3.52	.....
784	Wyandot	Carey	.....	.31		56.4	41.99	.....	.48	.....
785	"	"	.....	3.08		80.11	8.09	.....	5.72	.....
786	"	Upper Sandusky	.....	4.31		64.25	15.93	.....	8.18	.....

a CaO *b* MgO

THE UNITED STATES (*continued*)

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
751	....	U. S. geol. sur. Bul. 148, p. 261; F. W. Clarke, anal.	Trenton limestone
752	....	" " p. 262; C. Catlett, anal...	Depth 1112 ft
753	....	" " " "	Well no. 2, depth 1065 ft
754	....	" " " "	Doenze's well
755	....	" " p. 261; F. W. Clarke and R. B. Riggs, anal.	
756	Org. .73	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432; J. D. Lisle, anal.	J. W. Ruhl quarry
757	P_2O_5 .001	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432; Prof. E. Orton, anal.	O. D. Brown "
758	....	U. S. geol. sur. Bul. 148, p. 261..................	Findlay st. well, depth 975 ft
759	....	" 20th rep't, pt 6 cont'd, p. 432.......	N. E. Gregg & Co. quarry
760	....	" Bul. 148, p. 262; C. Catlett, anal....	Trenton limestone
761	....	Ohio geol. sur. 6:734; N. W. Lord, anal.	Newman quarry, Cap rock, Niagara
762	....	" " "	Newman quarry, bottom rock. Niagara
763	....	" " "	Wyman & Gregg, main rock, Niagara
764	....	" " "	Habbeler, main rock, Niagara
765	....	" " "	Holt, main rock, Niagara
766	....	U. S. geol. sur 20th rep't, pt 6 cont'd, p. 432; Prof. E Orton anal	J. Kingham quarry
767	....	U. S geol. sur. 20th rep't, pt 6 cont'd, p. 432; G. A. Kirchmaier, anal.	Duncan & Bussard quarry
768	....	Ohio geol. sur. 5:1109..............................	D. Hendricks quarry
769	....	" 6:725; N. W. Lord, anal	Dwyer; upper stone
770	....	U. S geol. sur. Bul. 148, p. 262; C. Catlett, anal....	Waggoner well
771	....	Ohio geol. sur. 6:737; N. W. Lord, anal	H. Rancamp & Co.
772	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432.......	W. E. Marsh quarry
773	....	Ohio geol. sur. 6:739; N. W. Lord, anal............	Niagara limestone
774	....	U S. geol. sur. 20th rep't, pt 6 cont'd, p. 432......	D. P. Lloyd & Co. quarry
775	....	" Bul. 148, p. 262; C. Catlett, anal ..	Loomis & Nyman well
776	....	" " " "	"
777	....	" 20th rep't, pt 6 cont'd, p. 433; O. Wulte, anal.	L. McCollum & Co.
778	....	U. S. geol. sur. Bul. 148, p. 261; F. W. Clarke, anal.	Well no. 3; gas rock
779	....	" 20th rep't, pt 6 cont'd, p. 432; Prof. E. Orton, anal.	Snowflake lime co.
780	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432; G. A. Kirchmaier, anal.	N B. Eddy
781	....	U S. geol. sur. 20th rep't, pt 6 cont'd, p. 432; Prof E. Orton, anal.	Sugar Ridge lime and stone co.
782	Org. .82	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 432; H Blanck, anal.	Doherty & Co.
783	....	U. S. geol. sur. Bul. 148, p. 261; F. W. Clarke and R. B. Riggs, anal	Air Line Junction
784	....	U. S. geol sur 20th rep't, pt 6 cont'd, p. 432; Prof. E. Orton. anal.	M. Daum & Son
785	....	U. S. geol. sur. Bul. 148, p. 262; C. Catlett, anal...	
786	....	" " " "	City well no. 2

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Pennsylvania									
787	Adams	Fairfield	10.3	1.5		85.23	2.78	.....	....	......
788	"	"	8.85	......	.6	86.91	3.11	.28	....	......
789	Armstrong.....	N. e. of Kittanning.	.....	1		96.785	1.278	.....	.37	....
790	Beaver..........	½ m. below Vauport	......	1.823		93.482	1.544	......	2.77	......
791	"	"	......	2.324		88.464	1.445	......	7.03	......
792	"	"	.....	1.291		91.607	1.566	.....	4.78	......
793	"	"	......	1.589		91.089	1.587	......	4.8	......
794	Bedford	Everett	4.48	.89	......	*a*30.18	*b*19.48	......	....	.....
795	Berks	Esterley	......	1.22		55.58	39.21	......	3.89	......
796	Blair	Near Altoona........	.....	.842		95.664	1.547	......	2.5	......
797	"	"	.....	.644		95.089	1.581	......	3	......
798	"	"	.....	.57		95 571	1.521	.....	3.02	......
799	"	Near Birmingham..	......	1.19		53.87	41.32	.....	2.91	......
800	"	6 m. s. w. of Birmingham	......	2.85		48.03	37.67	.....	10.38	......
801	"	Catharine township	......	.264		94.98	3.866	......	.91	......
802	"	Frankstown	1.06	....	....	*a*54.9	....	......	....	......
803	"	Hollidaysburg.......	......	.035	......	96.164	1.589	......	1.615	......
804	"	"	.....	.043	....	84.782	3.859	.....	10.85	......
805	"	Roaring Spring......	....	1.85		78.176	10.746	.....	8.57	......
806	"	Hollidaysburg.......	.....	.054	. .....	95 251	2.265	.....	1.8	......
807	"	Roaring Spring......	......	.64		91.892	2.875	......	4.38	......
808	"	R. R. s. of Roaring Spring	... ..	.234		54.571	44.18	......	1.33	......
809	....	Sarah furnace quarry	.....	.44		96.142	1.604	......	1.688	......
810	....	Springfield furnace quarry	......	1.126		78.196	17.51	.....	3.21	......
811	Bradford.......	1 m. e. of Burlington	.....	2.613	4.428	*a*41.048	*b*1.135	33.24	18.01	......
812	Butler...	West Winfield.......	......	1		95.1	1.12	......	2.78	......
813	Cambria..	Johnstown	....	3.39	....	34 301	21.65	......	27.873	......
814	Center..........	Near Bellefonte.....	......	& $FeCO_3$	.203	97.89	1.285	.....	.54	....
815	....	"		"	.32	98.322	1.17	......	.39	......
816	....	"	......	"	.377	97.532	1.21	....	.815	......
817	Chester	Downingtown.	.....	......	.37	54.15	45.2	......	....	......
818	Cumberland. ..	Greason.............	....	....	....	*a*39.26	*b*9	38.82	11.07	.18
819	Fayette	George township....	....	.543	$FeCO_3$ 1.657	80.647	2.217	......	10.77	1.01
820	....	3 m. n. e. of Uniontown	....	.812	$FeCO_3$ 5.178	66.471	17.711	.....	9.46	......
821	....	Uniontown....	......	.135	$FeCO_3$ 1 914	87.868	1.733	....	7.36	......

a CaO

THE UNITED STATES *(continued)*

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
787	Ign. .19	U. S. geol. sur. 20th rep't, pt 6, p. 441; F. Menger, anal.	W. H. Gelbach
788		U. S. geol. sur. 20th rep't, pt 6, p. 441; F. Menger, anal.	G. W. Musselman
789		Pa. geol. sur. MM, p. 298	Pine Creek furnace quarry
790		" p. 297	Severn quarry
791		" "	Powers quarry
792		" "	"
793		" "	Tygart quarry
794		U. S. geol. sur. 20th rep't, pt 6 cont'd p. 441	J. E. Thorpp
795		" " " " C. T. Davies, anal.	A. K. Stauffer
796		Pa. geol. sur. MM, p. 301	Bakers quarry
797		" " "	"
798		" " "	"
799		" " p. 307	Keystone zinc co. Siluro-Cambrian
800		" " "	Borie property, Siluro-Cambrian
801		" " p. 306	Mt Etna furnace quarry
802	Ign. 43.8	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441	J. K. McLanahan jr
803		Pa. geol. sur. MM, p. 302	Manning quarry
804		" " "	Loop quarry
805		" " p. 306	Rodman furnace quarry
806		" " p. 302	Creswell quarry
807		" " p. 306	Rodman furnace quarry
808		" " "	"
809		" " p. 302	Lower Helderberg
810		" " p. 306	Cambro-Silurian limestone
811		" " G, p. 38	W. B. Kline farm
812		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441	Winfield mineral co. quarry
813	$FeCO_3$ 8.7 FeS_2 1.268	Pa. geol. sur. MM, p. 295	Johnstown cement bed in A. J. Hawes quarry
814		" " p. 307	Shortlidge quarry, upper bed
815		" " "	" middle bed
816		" " "	" lower bed
817		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441	J. Copeland quarry
818	Organic .75	" Bul. 148, p. 255; E. A. Schneider, anal.	
819		Pa. geol. sur. MM, p. 287	Oliphant furnace quarry
820		" " p. 289	Redstone limestone; Lemont furnace quarry
821		" " p. 290	Lemont furnace quarry, Pittsburg limestone

*b*MgO

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Penn. *(cont'd)*									
822	Huntingdon ..	McAleavys Fort.....	......	1.439		88.687	1.85	......	8.23	......
823	"	Robertsdale.......	....	......	4.536	52.571	2.081	......	42.46	......
824	"	Broadtop..........	......	......	5.179	46.232	2.56	......	34.64	......
825	" ...	Saltillo	8.75	1.26	FeO .638	*a*39.537	*b*8.821	41.528	... .	....
826	" ...	"	5.32	.55	FeO .576	*a*47.08	*b*4.598	42.09	....	.02
827	"	"	33.22	14.066	FeO 3.342	*a*14.12	*b*9.571	24.592	....	1.005
828	"	Near Saltillo	......	& $FeCO_3$ 1.783		89.292	2.557	.....	5.3	......
829	" ...	"	......	& $FeCO_3$ 1.607		47.3	2.011	.....	49.03	......
830	"	Three Springs......	....	.23	$FeCO_3$ 1.642	90.904	2.162	......	5.7	......
831	"	"	......	& $FeCO_3$ .697		94.035	1.965	......	2.33	......
832	" ...	"	.....	& $FeCO_3$ 1.139		91.125	1.572	......	5.04	......
833	"	½ m. s. of Todd post-office	......	.18	$FeCO_3$ .683	92.323	1.089	......	4.64	......
834	Indiana	1½ m. s. w. of Five Points	.....	3.22		84.125	5.198	......	6.021	......
835	"	1 m. e. of Chambersville	....	2.12		84.407	2.8	......	9.15	......
836	"	2 m. s. of Jacksonville	..	1.7		89.821	1.801	......	5.43	......
837	"	1½ m. n. e. of Homer	......	4.19		72.264	6.493	.....	14.98	......
838	"	3 m. s. e. Blairsville.	.....	6.93		54.768	8.627	.....	27.23	......
839	"	¾ m. w. n. w. of Decker's Point	....	1.96		88.232	1.371	......	8.21	......
840	"	4½ m. e. n. e. of Blairsville	....	2.63		82.321	8.021	......	5.502	......
841	"	2 m. s. w. of Smithport	.....	4.36	$FeCO_3$ 8.078	36.214	16.883	......	32.79	......
842	"	2 m. s. w. of Smithport	......	7.38		58.75	16.005	......	15.06	......
843	"	1 m. e. of Blacklick station	......	3.54		78.768	2.421	......	13.79	......
844	"	½ m. s. w. from Richmond	.....	2.03		92.857	1.589	......	2.09	......
845	"	Blairstown	...	5.71		65.892	9.686	......	16.54	......
846	"	Smiths station	......	3.02		79.821	3.601	......	12.16	......
847	"	West Lebanon	......	2.83		82.768	2.875	......	10.327	......
848	Lancaster. ...	Chickies.............	.36	.31	......	51	48.49	......	....	......
849	"	Rheems	......	.11		97.95	.98	......	.96	......
850	Lawrence.	Near Wampum, Big Beaver township	.....	.805		94.214	1.732	......	2.79	......
851	" .	3 m. n. w. Mt Jackson, n. Beaver township	......	.632		95.768	1.097	......	1.97	......
852	"	Near New Castle....	......	1.563		93.34	1.46	.....	3.07	......
853	"	2 m. n. of Croton....	......	1.187		94.785	1.369	......	2.08	......
854	"	Youngstown	1.5	1.6		96.43	.4	......	....	......
855	Lebanon.........	Richland station....	.07	.19		99.02	.67	......	....	......
856	"	" ...	.39	.24		98.36	.91	....	....	......
857	Lehigh	Trexlertown	7.22	2.3		86.5	1.21	......	....	......
858	Mifflin	2 m. from Belleville.	......	.426		97.631	1.131	.....	.75	......

a CaO *b* MgO

THE UNITED STATES *(continued)*

No.	MISCELLANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
822		Pa. geol. sur. MM, p. 366	John Barr quarry
823		" " p. 367	Calcareous conglomerate
824		" " "	J. Diggins farm
825		" " p. 303	375 feet above bottom of Waterlime formation
826		" " "	190 feet above bottom of Waterlime formation
827		" " "	160 feet above bottom of Waterlime formation
828		" " "	125 feet from bottom. C. R. McCarthy
829		" " "	Specimen from flinty beds
830		" " p. 302	Hudson quarry, 70 feet above bottom of formation
831		" " "	Hudson quarry, 60 feet above bottom of formation
832		" " "	Hudson quarry, 50 feet above bottom of formation
833		" " p. 290	J. Whitney quarry
834		" " p. 292	S. Brown quarry; Freeport upper limestone
835		" " "	Groft Bros. quarry; Freeport upper limestone
836		" " "	S. C. Hazlett quarry; Freeport upper limestone
837		" " "	D. R. Griffith quarry
838		" " "	G. Livengood quarry
839		" " p. 293	S. Palmer quarry; Freeport lower limestone
840		" " "	P. Brown quarry
841		" " p. 294	A. Gorman, upper layer, Johnstown cement rock
842		" " "	A. Gorman, lower layer
843		" " "	Tyhawk quarry, main bench
844		" " p, 298	Isaac Simpson's
845		" " p. 366	G. M. Doty
846		" " p. 288	Sewickley limestone
847		" " p. 289	A. H. Fulton quarry, Pittsburg limestone
848		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441	Chickies iron co.
849		" " " "	W. L. Heisey & Co.
850		Pa. geol. sur. MM, p. 297	J. K. Shinn & Bros. quarry
851		" " "	McCord quarry
852		" " "	Green's, Marquis & Johnson quarries
853		" " "	Moffit quarry
854		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441	Carbon limestone co.
855		" " " " A. S. McCreath, anal.	J. C. Fisher
856		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; A. S. McCreath, anal.	S. A. Royer
857		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; H. R. Hartzel, anal.	I. Stettler
858		Pa. geol. sur. MM. p. 308	D. Campbell quarry

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Penn. (*cont'd*)									
859	Mifflin	A. Campbell quarry	......	1.258		81.178	13.398	....	4.53	......
860	''	''	......	1.36		70.214	24.415	......	4.05	......
861	''	1 m. from Belleville	......	1.422		54.285	36.109	......	8.01	......
862	''	Reedsville	1.69	1.36		95.75	2.08	......	....	......
863	''	''	.33	.61		96.24	2.86	......	....	......
864	Montgomery	Bridgeport L	2.95	1.35		*a*58.33	*b*37.37	......	....	......
865	''	''	1.58	.72		55.7	41.97	....	....	......
866	''	Norristown	......	.45		53.49	45.76	......	.2	......
867	''	''		.2		54.04	45.51	......	.25	......
868	Northampton	Freemansburg	2.18	1.61	.32	89.09	5.16	.....	....	......
869	Northumberland	Dalmatia L	....	6.8		*a*51.38	*b*.34	......	2.43	......
870	Somerset	Buckstown	....	3.317	FeCO$_3$ 3.069	51.921	3.639	......	37.94	......
871	''	Forwarsdtown	......	.455	FeCO$_3$ 3.314	80.588	8.445	......	4.803	1
872	''	Listie	....	2		92.12	2.35	....	3.53	......
873	''	2½ m. s. w. of Meyersdale	......	.972	FeCO$_3$ 2.239	72.6 3	12.614	......	9.18	......
874	''	¾ m. w. of Meyersdale	....	1.366	FeCO$_3$ 3.935	69.16	15.535	......	9.73	......
875	''	1 m. w. of Meyersdale	....	2.886	FeCO$_3$ 6.835	55.589	14.224	......	19.8	......
876	''	1 m. n. of Salisbury	......	1.548	FeCO$_3$ 5.282	74.801	6.734	......	11.51	......
877	''	2½ m. s. of Salisbury	.....	&FeCO$_3$ 1.825		86.625	6.152	.....	4.04	......
878	''	2½ m. n. of Salisbury	......	1.7	FeCO$_3$ 4.274	64.706	2.156	......	20.66	......
879	''	¾ m. n. of Ursina	.....	&FeCO$_3$ 1.986		90.803	2.738	......	3.74	......
880	''	3½ m. s. e. of Somerset	.....	&FeCO$_3$ 4.893		63.969	4.244	......	24.78	......
881	''	1¼ m. s. e. of Friedensburg	......	&FeCO$_3$ 2.972		86.778	2.908	......	6.04	......
882	''	Sipesville	......	&FeCO$_3$ 3.693		79.478	10.222	....	4.97	......
883	''	Stoystown	......	.34	FeCO$_3$ 1.798	88.139	1.854	......	5.64	......
884	''	Jenner Crossroads	......	.359	FeCO$_3$ 1.167	92.298	1.483	......	3.95	......
885	''	''	......	1.626	FeCO$_3$ 8.492	54.321	23.088	......	12.02	......
886	''	''	......	.403	FeCO$_3$ 4.789	69.261	13.773	....	10.76	......
887	''	Huskins run; Shade township	......	4.44	FeCO$_3$ 5.8	52.94	16.06	......	17.77	......
888	''	Near Davidsville	......	.261	FeCO$_3$ 1.503	90.541	2.134	.....	3.85	......
889	''	¾ m. n. of Scalp Level	......	&FeCO$_3$ 11.6		50.16	18.494	......	13.36	......
890	Sullivan	Near Millview	......	5.196		80.393	5.653	......	5.24	......
891	''	''	......	5.47		69	5.387	.....	17.85	......
892	Tioga	½ m. n. of Mansfield	......	2.269	2.142	*a*28.872	*b*1.117	23.227	41.7	......
893	Washington	1 m. e. of Washington	......	2.929		72.866	3.813	......	17.38	......

*a*CaO *b*MgO

THE UNITED STATES (*continued*)

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
859		Pa. geol. sur. MM, p. 308	Probably top of Calciferous
860		" " "	Bottom of Chazy
861		" " "	Greenwood ore bank limestone
862		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; R. Kent, anal.	J. B. Smith no. 1
863		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; R. Kent, anal.	" 2
864		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; C. F. Reader, anal	R. McCoy lime co.
865		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441.	"
866		" " " " Booth, Garrett & Blair, anal.	W. B. Rambo, quarry no. 1
867		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; Booth, Garrett & Blair, anal.	" " 2
868		U. S. geol sur. 20th rep't, pt 6 cont'd, p. 441; A. Bachman, anal.	G. W. Bachman
869		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441; Dr W. Frear, anal.	J. Yeager
870		Pa. geol. sur. MM, p. 366	Burkit farm
871		" " "	Harshberger quarry
872		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 441	Listie mining co.
873		Pa. geol. sur. MM, p. 286	Keystone coal and mfg. co. quarry
874		" " p. 287	Saylor Hill quarry
875		" " p. 291	Yoder's quarry
876		" " p. 287	J. M. Hayes quarry
877		" " p. 289	M. J. Beechy quarry; Redstone limestone
878		" " p. 290	S. S. Flickenger quarry
879	C 2.602	" " p. 291	Pittsburg coal, coke and iron co. Elklick limestone
880		" " p. 295	Johnstown cement rock in Zimmerman quarry
881		" " "	Reitz quarry
882		" " "	J. J. Pile quarry
883		" " "	Wilt quarry
884	C .55	" " "	J. H. Beans upper bench
885	C .93	" " "	" middle bench
886	C .59	" " "	" lower bench
887		" " p. 296	D. Rodgers quarry
888		" " "	Trevorrow quarry, Johnstown
889		" " "	J. Weaver quarry, Johnstown
890		" " p. 300	Lucke quarry upper bench
891		" " "	" lower bench
892		" " p. 299	G. R. Wilson
893		" " p. 284	

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Penn. (*cont'd*)									
894	Washington	1 m. n. of Cannonsburg	......	&$FeCO_3$ 3.306		68.867	14.649	......	13.3	.....
895	“	1 m. n. of Cannonsburg	......	3.523	$FeCO_3$ 3.625	48.823	20.021	......	22.52	.....
896	“	1 m. n. of Cannonsburg	......	&$FeCO_3$ 7 511		47.08	28.528	......	15 75	......
897	“	8 m. from Washington	......	&$FeCO_3$ 5 608		47.75	30.943	......	14.92	......
898	Westmoreland .	½ m. w. of Kelly's station	......	1.52		91.982	1.664	......	4.015	......
899	“	Salina	.....	2.72		94.643	1.144	...	.99	......
900	“	7 m. from Mt Pleasant	......	6.002	$FeCO_3$ 4.142	42.357	4.037	.....	38.24	......
901	York	½ m. w. of Mengis Mill station	.....	1.138	896 FeO 2.443	*a*36.816	*b*5.019	35.55	16.65	.35
902	“	½ m. w. of Mengis Mill station	......	1.93	5 524 FeO 2.228	*a*38.5	*b*.814	31 632	18.21	1.055
903	“	Wrightsville	.56	.66		154.26	44 51	......	....	.....
904	“	Hellam	.12	.14		93.14	6.51	......	....	......
	Rhode Island									
905	Providence.	Lime Rock	......	309	.011	88.233	8.797	......	2.748	.04
	South Dakota									
906	Lawrence	Deadwood	.....	tr.		*a*33.8	*b*15.7	......	1.8	......
	Tennessee									
907	Franklin	Sherwood L	.56	.22		*a*97.89	1.05	......	....	......
908	Houston	Erin L	.....	.13	.23	*a*97.82	*b*.12	......	.43	......
909	Knox	Knoxville	.17	.04	.23	*a*55.47	*b*.3	43.63	....	.21
	Texas									
910	Coryell.........	Oglesby	....	......	.35	*a*54.02	*b*.12	43.96	1.09	.....
911	Travis	McNeil L	....	.15 .16		*a*97.46 *a*97.82	....	......	.25 .15	und. .73 und. .85
	Vermont									
912	Addison	Leicester Junction.L	.383	....	.647	*a*98.262	*b*.290	......	....	.....
913	Bennington	North Pownal L	.27	.11	.08	*a*98.14	*b*1.4	......	....	......
914	Franklin	Highgate Springs...	4	.1		*a*55.83	*b*tr.	43 65	....	......
915	“	St Albans..........L	....	tr.	tr.	*a*99.23	*b*.6	......	.14	......
916	“	Swanton L	tr.	......	tr.	*a*98.47	1.12	.45	....	......
917	“	“ L	.1	tr.	.....	*a*99.29	.46	.....	....	......
918	“	“ L	.02	....	....	*a*98.84	.12	1.02	....	......
919	Rutland	Proctor	......	.2		*a*55	*b*.25	44.02	.35	......
920	“	“	......	....	$FeCO_3$ .053	96.3	3.06	......	.63	.....
921	“	“	......	....	$FeCO_3$ .034	98.37	.79	....	.63	......
922	“	West Rutland.......	.....	.3		*a*55.27	*b*.28	43 82	.28	......
923	“	“	......	.2		*a*55.26	*b*.15	43 66	.4	.....
924	“	“	....	.15		*a*55.50	*b*tr.	43.65	.7	......

*a*CaO *b*MgO

THE UNITED STATES (*continued*)

No.	MISCEL-LANEOUS	REFERENCE AND ANALYST	OWNER LOCATION AND REMARKS
894	....	Pa. geol. sur. MM, p. 285	Uniontown limestone, lower division, upper layer
895	....	'' '' ''	Uniontown limestone, lower division, middle layer
896	....	'' '' ''	Uniontown limestone, lower division, bottom layer
897	....	'' '' ''	Uniontown limestone, Shaner property
898	....	'' '' p. 293	Wining & Cuisan quarry
899	....	'' '' ''	Kier Bros. quarry
900	....	'' '' p. 367	J. Freeman
901	....	'' '' p. 308	
902	....	'' '' ''	
903	....	U. S. geol. sur. 20th rep't. pt 6 cont'd, p. 441........	Steacy & Co. quarry
904	....	'' '' '' ''	''
905	....	'' '' ''p. 442; J. H. Appleton, anal.	H. Harris quarry
906	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 443; J. V. N. Door, anal.	Deadwood & Delaware smelting co.
907	....	U. S. geol sur 20th rep't, pt 6 cont'd, p. 444	Gager lime and mfg. N. co.
908	....	'' '' '' p. 443	Arlington lime co.
909	....	'' Bul. 148, p. 258; L. G. Eakins, anal.	
910	SO_3 .17 Org .52	'' 20th rep't, pt 6 cont'd, p. 444; H. H. Harrington, anal	D. R. Boone quarry
911		U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 444........	Austin White lime co. analysis of lime
		'' '' '' ''	Austin White lime co.
912	....	'' '' '' p. 455........	Brandon lime and marble co.
913	....	'' '' '' '' R. Shuppaus, anal.	Follet Bros.
914	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 456; S. P. Sharpless, anal.	L. H. Felton
915	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 456; F. C. Robinson. anal.	W. B. Fonda
916	....	U. S. geol. sur. 20th rep't, pt 6 cont'd, p. 455. ...	J. P. Rich, no. 1
917	FeO .12	'' '' '' ''	'' 2
918	....	'' '' '' ''	'' 3
919	Org. none	'' 18th rep't, pt 5 cont'd, p. 986........	Marble
920	Org. .004	'' '' '' ''	Light marble
921	MnO_2 .005 Org. .08	'' '' '' ''	Dark ''
922	....	'' '' '' p. 985	Blue ''
923	....	'' '' '' ''	White ''
924	....	'' '' '' ''	Statuary ''

L = Analysis of burned lime

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	Vermont (*con.*)									
925	Rutland	West Rutland	......	....	....	*a*55.15	*b*.57	44	.22	......
926	"	"	.....	....	....	*a*54.95	*b*.59	43.8	.62	.....
	Virginia									
927	Augusta	Staunton	7.37	1.92	.29	*a*28.39	*b*18.3	41.85	....	.49
928	Frederick	Winchester	2.68	1.68		80 6	14.48	......	....	.56
929	"	N. w. turnpike, w. of Winchester	1.3	.12		88.64	9.6	......	....	.44
930	Montgomery	2 m. from Christiansburg road to Blacksburg	6.5	.84		55.8	*a*35 34	......	....	......
931	"	N. mountain, Price's road	7.44	1.16		52.2	38.4	.....	....	.8
932	Orange	1½ m. from Gordonsville	19.6	.8		79.2	tr.	......	....	.4
933	"	5 m. from Gordonsville	3.28	1.28		51.72	42.72	......	....	1
934	Page	....	1.48	1.6		70.16	25.96	......	....	.8
935	"	Luray	5.5	.77		78	11.37	......	....	4.86
936	"	Shenandoah	5.4	.8		47.48	45.8	......	....	.56
937	Shenandoah	½ m. w. of New Market	4.5	.84		86.16	....	......	....	6.5
938	"	New Market	7.6	.23		81	10.6	......	....	.52
	West Virginia									
939	Berkeley	Marlowe L	.....	.26		*a*98.44	*b*.98	.32	.18	......
940	Grant	Knobly mountain	4.56	.72		90.08	4	......	....	.64
941	"	Near Petersburg	6	1.52		88.52	3.24	.....	....	.72
942	Greenbrier	Fort Spring	.....	2.02		90.11	2.49	......	5.04	.34
943	"	On C. & O R. R.	.....	1.12		93.76	.29	......	3.92	.91
944	"	Blue Sulphur Springs	.4	.48		98.2	......	.....	....	.24
945	"	Muddy Creek mountain	1.2	.12		88.64	9.6	.....	....	.44
946	"	Snow Flake	.....	1.46	....	96.46	1.11	......	.97	......
947	Harrison	Near Clarksburg	.72	.96		95 52	1.88	.....	.92	......
948	Jefferson	Harpers Ferry	6.68	.52		81.16	10.8	.....	....	.84
949	"	2 m. s. w. Harpers Ferry	1.68	.48		53.88	43.4	.....	....	.56
950	"	4 m s. w. Harpers Ferry	......	tr.		95 86	1.46	......	1.83	.85
951	"	Charlestown	42.5	1.5	2	38.66	9.5	......	.....	5.84
952	"	Shepherdstown	38.93	4.17		32.17	18.36	......	....	......
953	"	"	42.9	2.1		23.9	24.36	......	....	6.74
954	"	"	12.6	7		67.5	8.36	.....	....	4.54
955	Kanawha	Two Mile creek	1.76	.8		83.92	2 8	......	....	.72
956	"	"	1.6	1.6		96.2	tr.	......	....	.6
957	"	Big Buffalo creek	18.48	2.16		73.44	5.32	.....	....	.6
958	"	Little Buffalo creek	18.72	1.4		72.52	6.8	......	....	.56
959	"	Eighteen Mile creek	31.92	3.68		55.96	7.6	......	....	.84

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957		" " p. 525	
958		" " "	
959		" " "	3 m. from mouth

*b*MgO

ANALYSES OF LIMESTONES OF

No.	STATE AND COUNTY	PLACE	SiO_2	Al_2O_3	Fe_2O_3	$CaCO_3$	$MgCO_3$	CO_2	INSOLUBLE	WATER
	West Va. (*con.*)									
960	Kanawha........	Coal river, lowest falls	1.68	.48		83.96	13.2	......	....	.68
961	"	Tyler's creek........	17	5.2		75.8	tr.	......	....	2
962	Mason	Point Pleasant......	9.68	3.52		79.84	6.28	......	....	.68
963	Marshall........	Moundsville narrows	1.53		.96	[a]53.26	[b].93	43.16	....	.1
964	"	"	10.33		.9	[a]48.02	[b]1.08	39.18	....	.05
965	Mineral.........	Patterson's creek...	4.96	.76		92.44	1.4	......	....	.68
966	Monongalia.....	Greenville Furnace.	7.64	2.52		88.32	....	......	....	.76
967	Monroe.........	Red Sulphur Springs	6.2	1.2		90.92	tr.	.....	....	.44
968	"	Union.	1.88	.56		95.92	....	.....	....	.4
969	"	Dunlaps Creek......	2.96	.52		86.52	9.52	.....	....	.48
970	"	Little North mountain	10.8	1		78 48	9.2	....	....	.52
971	Ohio............	Willow grove.......	7.61	4.1		85.95	1.38	.....	....	.96
972	Pleasants	South side Rapidanne river	2	.52		90.4	6.44	......	....	.64
973	Preston	Jenkins lime kiln....	5.8	1.16		89 76	2.32	......	....	.92
974	....	R. Forman's........	1.36	.4		91.8	5.72	....	....	.76
975	....	Below coal no. 2	.....	3.12		79.52	2.8	......	13.8	1.24
	Wisconsin									
976	Calumet	Brillion..............	.59	.36	....	55.09	43.96	......	....	......
977	Dodge	Knowles		.24		54.3	45.32	......	.28	......
978	Door	Sturgeon Bay.......	1.09	.33		54.42	44.17	......	....	......
979	Fond du Lac...	Hamilton............	......	.1	.26	54 25	44.48	......	.67	.11
980	Milwaukee	Milwaukee	17.56	1.41	3.03	45.54	32.46	......	....	......
981	"	"	17.56	1.4	2.24	48.29	29.19	......	....	......
982	"	"	16.99	5	1.79	41.34	34.88	.....	....	......
983	Outagamie.....	Duck Creek.........	3.17	1.95		49 97	44.58	.....	....	......
984	Ozaukee........	Grafton	.37	.92		52.57	45.34	......	.62	......
985	Sheboygan	Sheboygan..........	.46	1.1		55 49	42.31	.64	....	......
986	Waukesha	Genesee.............	6 32	1.02		50.96	41.75	.....	....	......
987	"	Lannon..............	3.96	1.68		52 29	42.27	.....	....	......
988	Winnebago	....	3.01	1.82	.18	51.97	42.91	......	....	......

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962		“ “ “	
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964		“ “ “ “	Upper “
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968		Description of resources of W. Va. Summers 1893, p. 88; W. B. Rogers	
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970		Description of resources of W. Va. Summers 1893, p. 88; W B. Rogers	
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PLATE 103

Map of New York state showing distribution of limestones